Northeast Fisheries Science Center Reference Document 11-17

52nd Northeast Regional Stock Assessment Workshop (52nd SAW):

Assessment Report

by Northeast Fisheries Science Center

September 2011

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11-10 *Evaluating sea turtle injuries in Northeast fishing gear*, by C Upite. July 2011.

11-11 *52nd Northeast Regional Stock Assessment Workshop (52nd SAW): Assessment summary report*, by Northeast Fisheries Science Center. July 2011.

11-12 In preparation.

11-13 *Description of the 2009 oceanographic conditions on the Northeast U.S. Continental Shelf*, by PS Fratantoni, T Holzwarth-Davis, C Bascuñán, and MH Taylor. September 2011.

11-14 In preparation.

11-15 *Frequency of whale and vessel collisions on the US Eastern Seaboard: ten years prior and two years post ship strike rule*, by RM Pace. September 2011.

11-16 *Proceedings of the Pollock Ageing Workshop 13 - 14 July 2010, Boothbay Harbor, Maine*, by WJ Duffy, WE Gross, C Nelson, and S Emery. September 2011.

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NOAA National Marine Fisheries Service, 166 Water St., Woods Hole, MA 02543

US DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts

September 2011

Northeast Fisheries Science Center Reference Documents

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Editorial Treatment: To distribute this report quickly, it has not undergone the normal technical and copy editing by the Northeast Fisheries Science Center's (NEFSC's) Editorial Office as have most other issues in the NOAA Technical Memorandum NMFS-NE series. Other than the four covers and first two preliminary pages, all writing and editing have been performed by the authors listed within.

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Foreword

The Northeast Regional Stock Assessment Workshop (SAW) process has three parts: preparation of stock assessments by the SAW Working Groups and/or by ASMFC Technical Committees / Assessment Committees; peer review of the assessments by a panel of outside experts who judge the adequacy of the assessment as a basis for providing scientific advice to managers; and a presentation of the results and reports to the Region's fishery management bodies.
Starting with SAW-39 (June 2004), the process was revised in two fundamental ways. First, the Stock Assessment Review Committee (SARC) became smaller panel with panelists provided by the Independent System for Peer Review (Center of Independent Experts, CIE). Second, the SARC provides little management advice. Instead, Council and Commission teams (e.g., Plan Development Teams, Monitoring and Technical Committees, Science and Statistical Committee) formulate management advice, after an assessment has been accepted by the SARC. Starting with SAW-45 (June 2007) the SARC chairs were from external agencies, but not from the CIE. Starting with SAW-48 (June 2009), SARC chairs are from the Fishery Management Council's Science and Statistics Committee (SSC), and not from the CIE. Also at this time, some assessment Terms of Reference were revised to provide additional science support to the SSCs, as the SSC's are required to make annual ABC recommendations to the fishery management councils.

Reports that are produced following SAW/SARC meetings include: An *Assessment Summary Report* - a summary of the assessment results in a format useful to managers; an *Assessment Report* – a detailed account of the assessments for each stock; and the SARC panelist reports – a summary of the reviewer's opinions and recommendations as well as individual reports from each panelist. SAW/SARC assessment reports are available online at http://www.nefsc.noaa.gov/nefsc/publications/series/crdlist.htm. The CIE review reports and assessment reports can be found at *http://www.nefsc.noaa.gov/nefsc/saw/*".

The 52nd SARC was convened in Woods Hole at the Northeast Fisheries Science Center, June 6-10, 2011 to review benchmark stock assessments:
of three winter flounder (*Pseudopleuronectes americanus*) stocks in the Southern New England/Mid-Atlantic (SNE/MA), Georges Bank (GBK), and Gulf of Maine (GOM) regions. CIE reviews for SARC52 were based on detailed reports produced by NEFSC Assessment Working Groups. This Introduction contains a brief summary of the SARC comments, a list of SARC panelists, the meeting agenda, and a list of attendees (Tables 1 – 3). Maps of the Atlantic coast of the USA and Canada are also provided (Figures 1 - 5).

Outcome of Stock Assessment Review Meeting:

Based on the Review Panel reports (available at http://www.nefsc.noaa.gov/nefsc/saw/ under the heading "SARC 52 Panelist Reports"), the SARC review committee concluded that for the **SNE/MA** winter flounder assessment all Terms of Reference were addressed satisfactorily. The statistical catch-age model used for SNE/MA assessment is considered to be a scientifically credible approach and provides a reasonable basis for fisheries management advice. In 2010, this stock was overfished but overfishing was not occurring.

The Terms of Reference for the **GBK** winter flounder assessment were satisfactorily addressed. The VPA model used was a scientifically credible approach and provides a reasonable basis for fisheries management advice. A statistical catch-age model should be considered for the GBK stock as there may be more uncertainty here associated with catch and discards than would be appropriate for the assumption of true known catches as is made in a VPA analysis. In 2010 the GBK winter flounder stock was not overfished and overfishing was not occurring.

The Terms of Reference for the **GOM** winter flounder assessment were partially addressed. The GOM statistical catch-age model could not account for conflicting trends in the catch and survey information, and was not accepted. However, the accepted fall back analysis of the area-swept method provides a reasonable gauge of overfishing status and provides time trends in biomass. Overfishing does not appear to be taking place in 2010. It was not possible at the meeting to determine whether or not the stock is overfished.

For all of these assessments, the SARC felt that the discussion of stock vulnerability could have addressed biological issues more directly (e.g., life history, longevity, fecundity, productivity, or whether the species or stock is overly susceptible to fishing or environmental conditions). While the length-based calibrations between vessels were informative and appeared appropriate, this method might be considered for additional peer review. A method was developed for combining information on winter flounder across regions to help inform the spawner-recruit relationships used in developing projections and biological reference points (for details on the method see the Review Panel Summary Report and the Appendix of the Stock Assessment Report).

CIE review reports can be found at *http://www.nefsc.noaa.gov/nefsc/saw/* under the heading “SARC 52 Panelist Reports”.

Table 1. 52nd Stock Assessment Review Committee Panel.

<u>SARC Chairman (NEFMC SSC):</u>

Dr. Patrick Sullivan
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Table 2. Agenda, 52nd Stock Assessment Review Committee Meeting.

52nd Northeast Regional Stock Assessment Workshop (SAW 52) Stock Assessment Review Committee (SARC) Meeting

June 6-10, 2011

Stephen H. Clark Conference Room – Northeast Fisheries Science Center
Woods Hole, Massachusetts

AGENDA (version: 3 June 2011)

TOPIC	PRESENTER(S)	SARC LEADER	RAPPORTEUR

Monday, June 6

1 – 1:15 PM Welcome, Introduction, Agenda, Conduct of Meeting	**James Weinberg**, SAW Chair; **Patrick Sullivan**, SARC Chair		
1:15 – 3:15 Assessment Presentation (A. SNE Winter flounder)	**Mark Terceiro**	**TBD**	**Tony Wood**
3:15 – 3:30 Break			
3:30 – 5:30 SARC Discussion w/ presenters (A. SNE Winter flounder)	**Pat Sullivan**, SARC Chair		**Tony Wood**

Tuesday, June 7

8:30-10:30 AM Assessment Presentation (B. GBK Winter flounder)	**Lisa Hendrickson**	**TBD**	**Toni Chute**
10:30-10-45 Break			
10:45 – 12:30 SARC Discussion w/ presenters (B. GBK Winter flounder)	**Pat Sullivan**, SARC Chair		**Toni Chute**
12:30 - 1:45 Lunch			
1:45 – 3:45 Assessment Presentation (C. GOM Winter flounder)	**Paul Nitschke**	**TBD**	**Jessica Blaylock**
3:45 – 4:00 Break			
4:00 – 5:45 SARC Discussion w/ presenters (C. GOM Winter flounder)	**Pat Sullivan**, SARC Chair		**Jessica Blaylock**

(Evening Social/Dinner – Probably at BBC, Falmouth, 7pm)

Wednesday, June 8

8:45 – 11	Revisit w/ presenters (A.)		
		Pat Sullivan, SARC Chair	**Tony Wood**
11 - 11:15	Break		
11:15 – 12:30	Revisit w/ presenters (B.)		
		Pat Sullivan, SARC Chair	**Toni Chute**
12:30 – 1:45	Lunch		
1:45 – 2:45	cont. Revisit w/ presenters (B.)		
		Pat Sullivan, SARC Chair	**Toni Chute**
2:45 - 3	Break		
3 – 5:15	Revisit w/ presenters (C.)		
		Pat Sullivan, SARC Chair	**Jessica Blaylock**

Thursday, June 9

8:45 – 11	Review/edit Assessment Summary Report (A.)		
		Pat Sullivan, SARC Chair	**Tony Wood**
11 - 11:15	Break		
11:15 – 12:30	Review/edit Assessment Summary Report (B.)		
		Pat Sullivan, SARC Chair	**Toni Chute**
12:30 – 1:45	Lunch		
1:45 – 2:45	cont. Review/edit Assessment Summary Report (B.)		
		Pat Sullivan, SARC Chair	**Toni Chute**
2:45 - 3	Break		
3 – 5:15	Review/edit Assessment Summary Report (C.)		
		Pat Sullivan, SARC Chair	**Jessica Blaylock**

Friday, June 10

9:00 - 5:30 PM SARC Report writing. (closed meeting)

*All times are approximate, and may be changed at the discretion of the SARC chair. The meeting is open to the public, except where noted.

Table 3. 52nd SAW/SARC, List of Attendees

Name	Affiliation	Email
James Weinberg	NEFSC	James.weinberg@noaa.gov
Paul Rago	NEFSC	Paul.Rago@noaa.gov
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Gary Shepherd	NEFSC	gary.shepherd@noaa.gov
Larry Alade	NEFSC	Larry.alade@noaa.gov
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Dvora Hart	NEFSC	Deborah.hart@noaa.gov

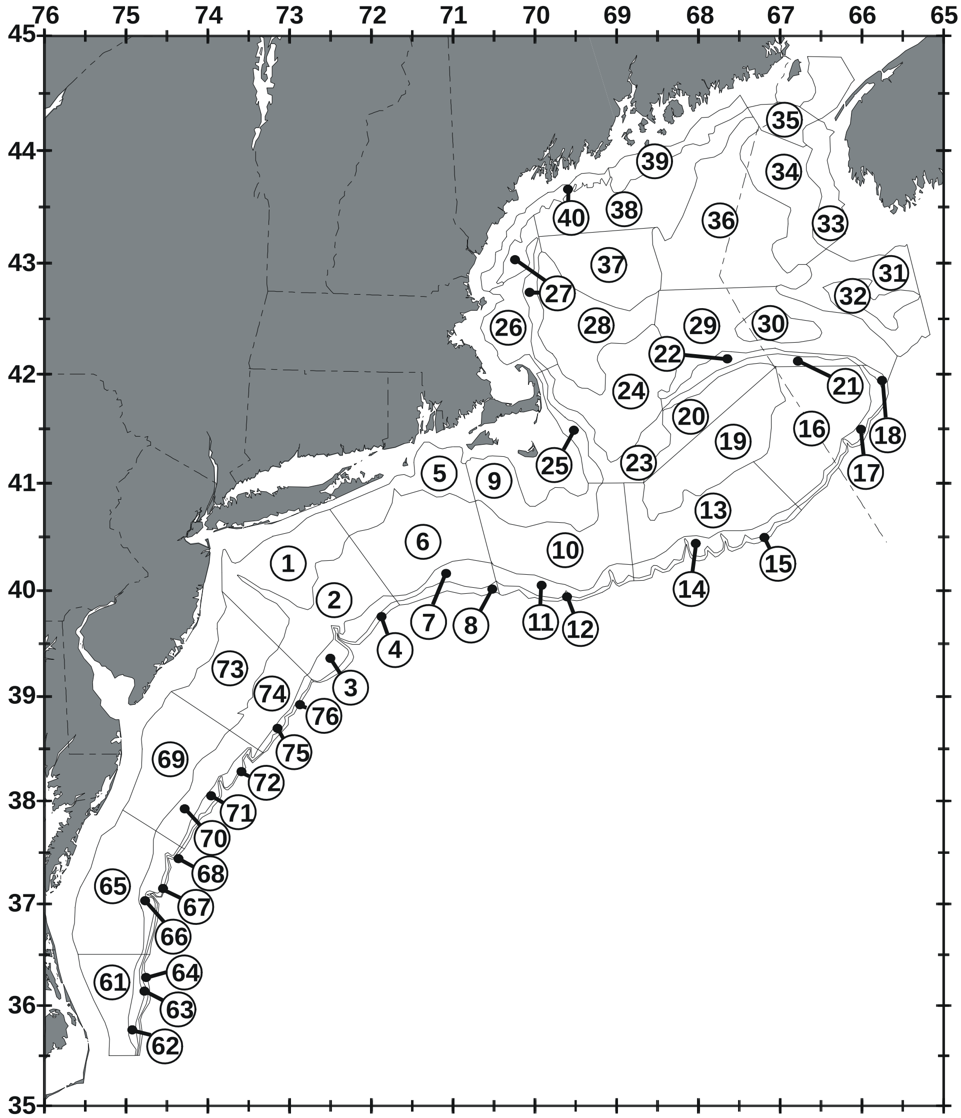

Figure 1. Offshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys.

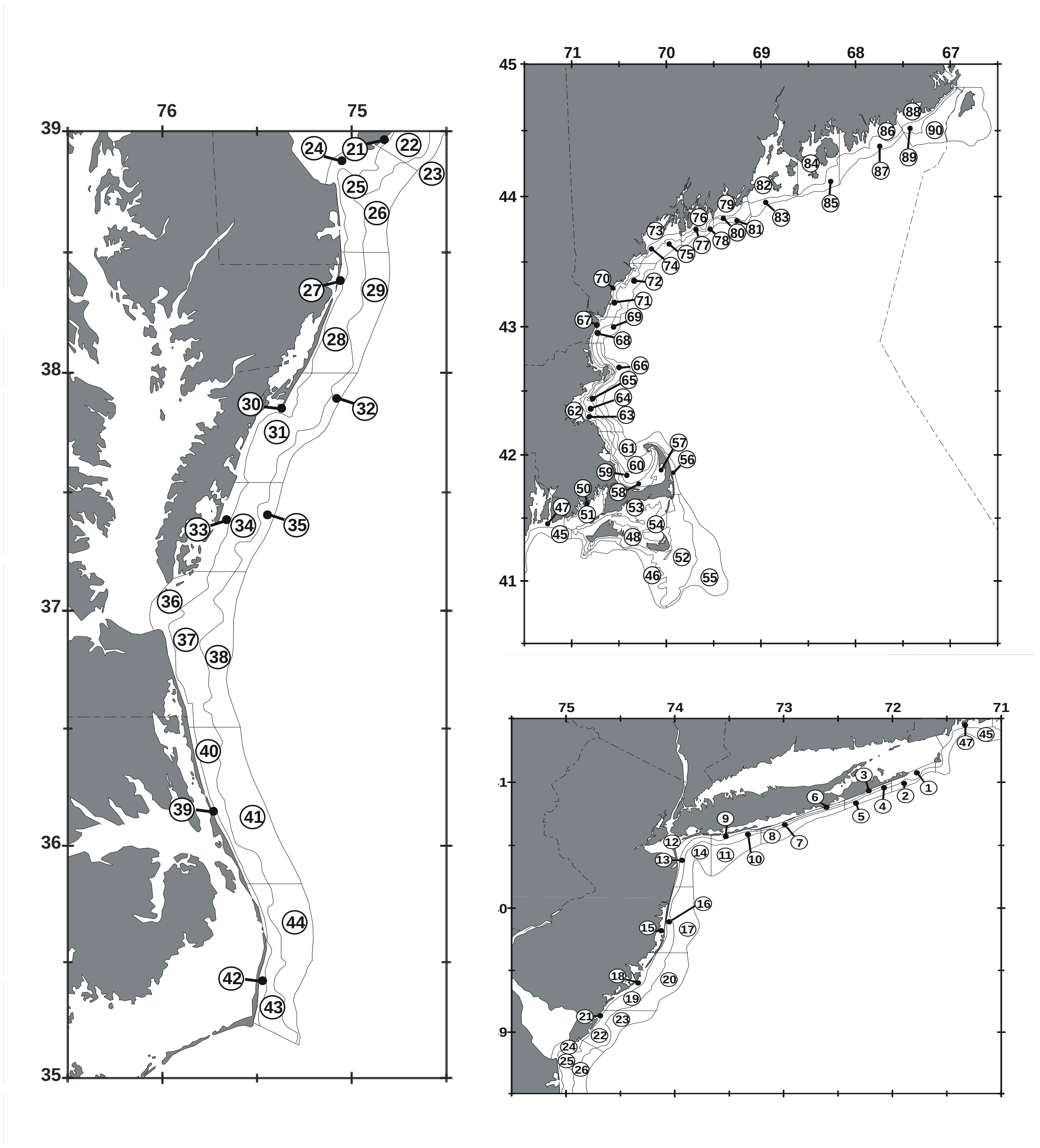

Figure 2. Inshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys.

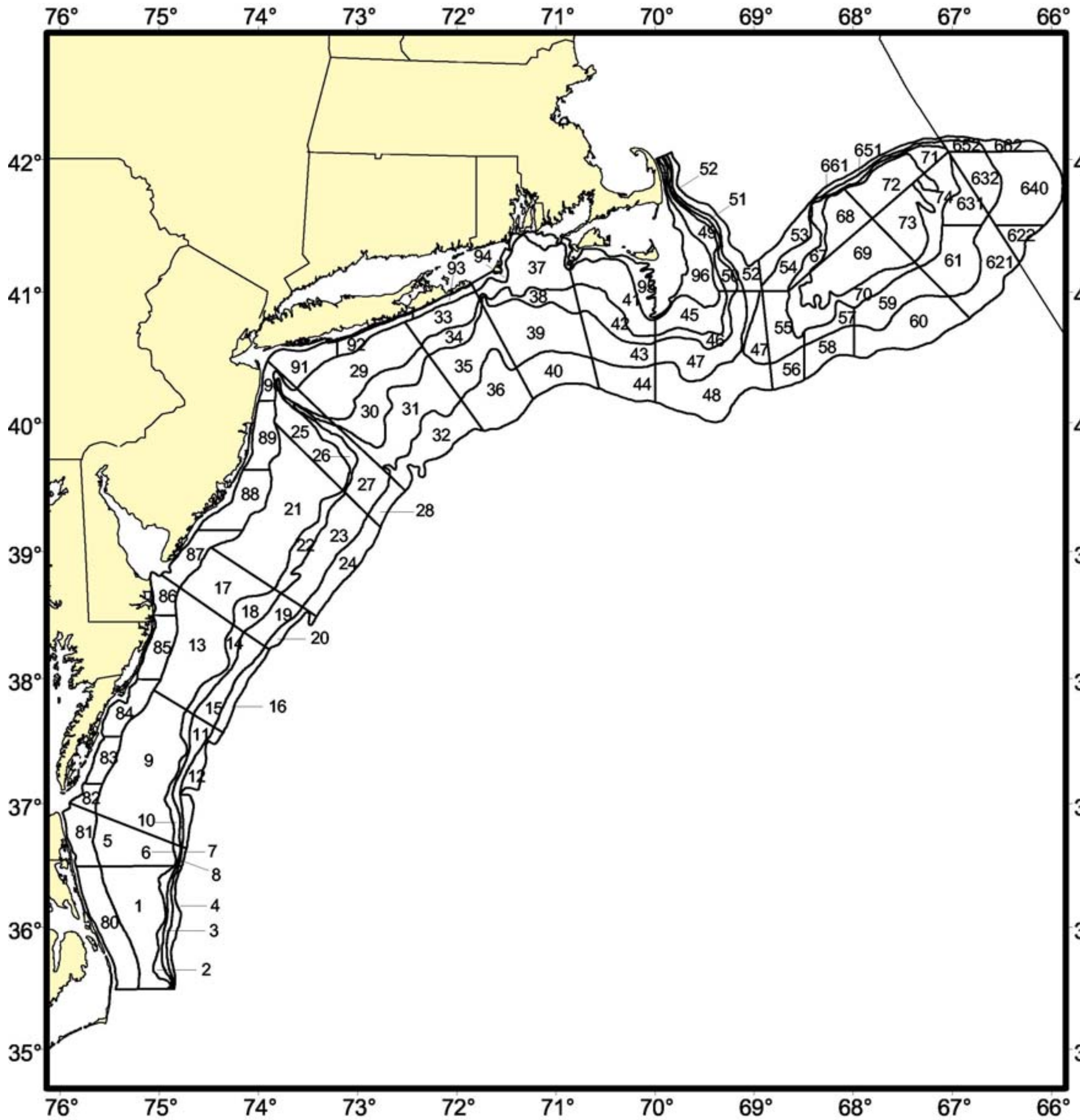

Figure 3. Depth strata sampled during Northeast Fisheries Science Center clam dredge research surveys.

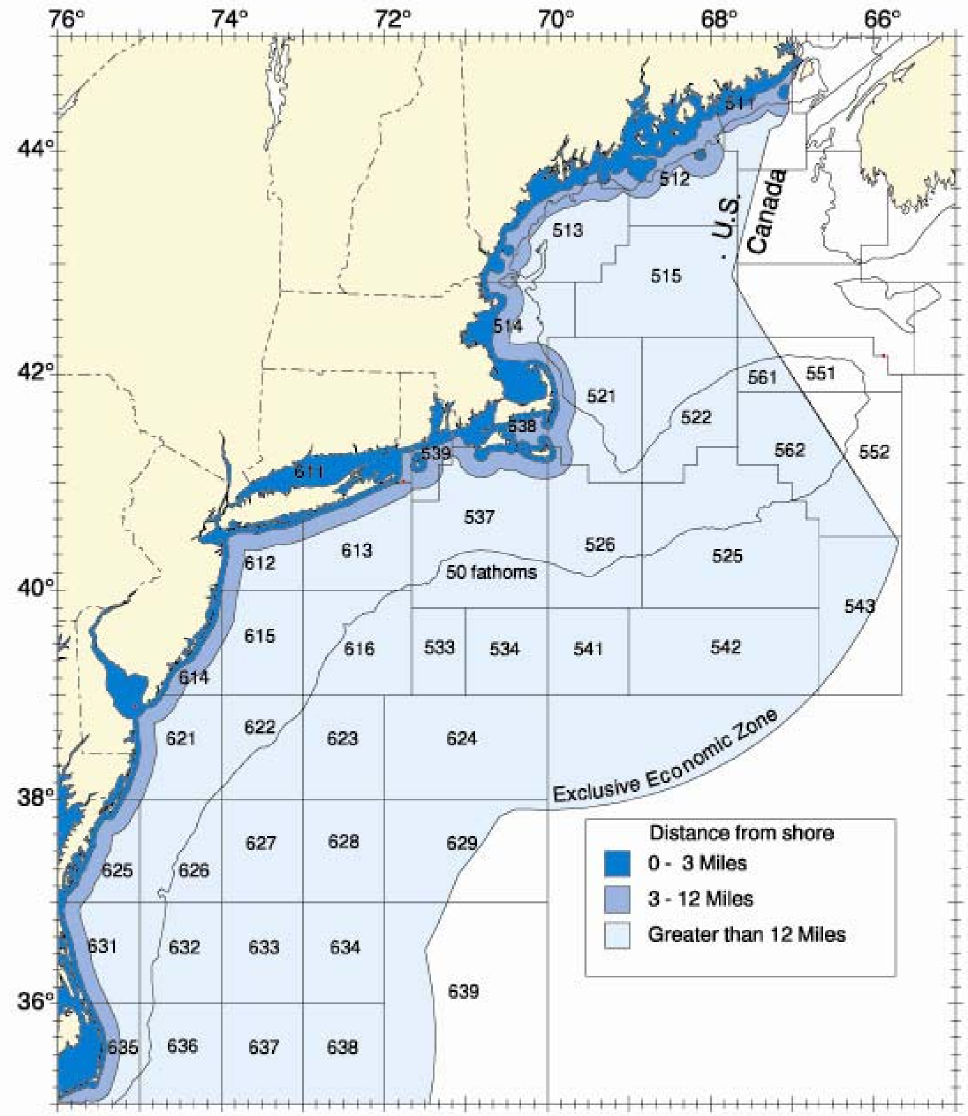

Figure 4. Statistical areas used for reporting commercial catches.

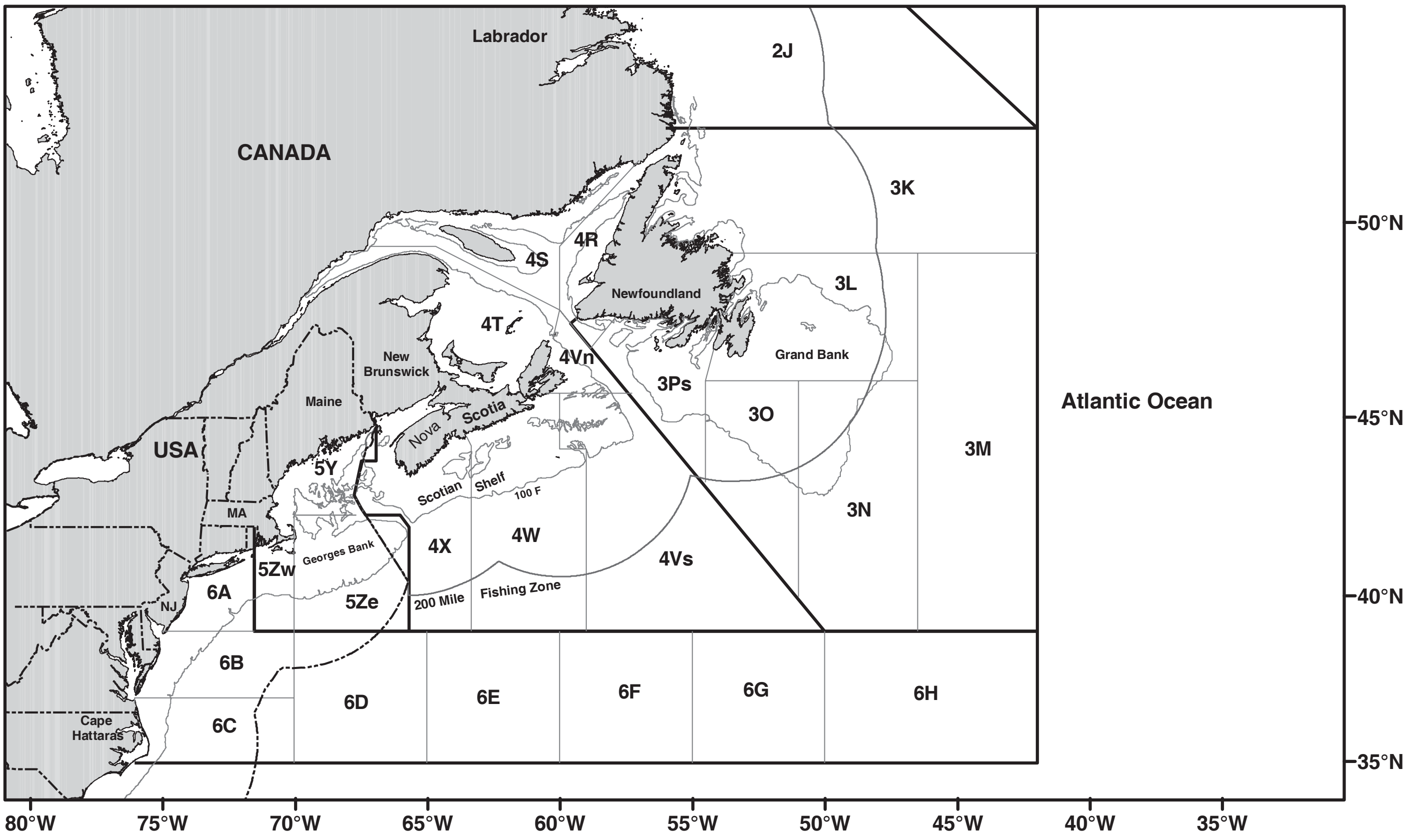

Figure 5. Catch reporting areas of the Northwest Atlantic Fisheries Organization (NAFO) for Subareas 3-6.

A. SOUTHERN NEW ENGLAND / MID-ATLANTIC (SNE/MA) WINTER FLOUNDER STOCK ASSESSMENT FOR 2011

The Southern Demersal Working Group (SDWG) prepared the stock assessment. The SDWG met during April 19-21, April 26-28, and May 3-5, 2011 at the Northeast Fisheries Science Center, Woods Hole, MA, USA.

The following participated in all or part of the meetings:

Name	Affiliation	email
Paul Nitschke	NEFSC	paul.nitschke@noaa.gov
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SAW 52 Terms of Reference

A. Winter flounder (Southern New England Stock)

1. Estimate catch from all sources including landings and discards. Characterize the uncertainty in these sources of data.

2. Present survey data being considered and/or used in the assessment (e.g., regional indices of abundance, recruitment, state and other surveys, age-length data, etc.). Characterize uncertainty in these sources of data.

3. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series (integrating results from TOR-5), and estimate their uncertainty. Include area-swept biomass estimates. Investigate if implied survey gear or catchability estimates are reasonable. Include a historical retrospective analysis to allow a comparison with previous assessment results.

4. Perform a sensitivity analysis which examines the impact of allocation of catch to stock areas on model performance (in TOR-3).

5. Examine the effects of incorporating environmental factors in models of population dynamics (e.g., spring water temperatures in an environmentally-explicit stock recruitment function).

6. State the existing stock status definitions for "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, and F_{MSY}) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

7. Evaluate stock status (overfished and overfishing) with respect to the "new" BRPs (from TOR 6), and with respect to the existing BRPs (from a previous accepted peer review) whose values have been updated.

8. Develop and apply analytical approaches and data that can be used for conducting single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs) under a set of alternative harvest scenarios. If the stock needs to be rebuilt, take that into account in these projections.

   a. Provide numerical short-term projections (3-5 yrs, or through the end of the rebuilding period, as appropriate). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions about the most important uncertainties in the assessment (e.g., terminal year abundance, variability in recruitment).
   b. Take into consideration uncertainties in the assessment and the species biology to describe this stock's vulnerability (see "Appendix to the SAW TORs") to becoming or remaining overfished, and how this could affect the choice of ABC.

c. Develop plausible hypotheses (e.g., mixing among the three stocks) which might explain any conflicting trends in the data and undertake scenario analyses to evaluate the consequences of these alternate hypotheses on ABC determination.

9. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

Executive Summary

The Southern Demersal Working Group (SDWG) met in April and May of 2011 to develop stock assessments for the Southern New England/Mid-Atlantic (SNE/MA) stock of winter flounder. The SDWG met within the process of the Northeast Regional SAW 52 and addressed nine Terms of Reference, as follows:

1. Estimate catch from all sources including landings and discards. Characterize the uncertainty in these sources of data.

Commercial fishery landings reached an historical peak of 11,977 metric tons (mt) in 1966, then decreased through the 1970s, peaked again at 11,176 mt in 1981, and then steadily decreased to 2,128 mt in 1994. Commercial landings then increased to 4,556 mt in 2001 and then decreased to only 174 mt in 2010. The Proportional Standard Error (PSE) of commercial landings has averaged less than 1%. Recreational fishery landings peaked in 1984 at 5,510 mt but decreased thereafter, with only 28 mt estimated for 2010. The PSE of the recreational landings has averaged about 27%. Commercial fishery discards for 1981 to 1993 were estimated from length frequency data from the NEFSC and MADMF trawl surveys, commercial port sampling of landings at length and Fishery Observer sampling of landings and discard at length. The Standardized Bycatch Reporting Method (SBRM) has been used for estimation of SNE/MA winter flounder commercial fishery discards for 1994 and later years. Commercial fishery discard losses peaked in the early 1980s at 1,000-1,500 mt per year and have decreased to less than 200 mt per year since 1997. A discard mortality rate of 50% was applied to the commercial live discard estimates. The PSE of the commercial fishery discards has averaged 27%. Recreational fishery discard losses peaked in 1984-1985 at about 700,000-750,000 fish or 150-200 mt and then decreased to less than 100,000 fish or 20 mt per year since 2000. A discard mortality rate of 15% was applied to recreational live discard estimates. The PSE of the recreational discards has averaged 30%.

2. Present survey data being considered and/or used in the assessment (e.g., regional indices of abundance, recruitment, state and other surveys, age-length data, etc.). Characterize uncertainty in these sources of data.

The NEFSC winter, spring and fall bottom trawl surveys provided long time series of fishery-independent indices for SNE/MA winter flounder. The strata set defined for SNE/MA winter flounder was revised in this assessment to use a consistently sampled strata set over the historical time series and into the future. NEFSC indices generally increased from a low point in the early to mid-1970s to a peak by the early 1980s. NEFSC survey indices reached near- or record low levels in the late 1980s-1990s. Indices from the three survey series generally increased during the late 1990s, but have since decreased again. The Fisheries Survey Vessel (FSV) Albatross IV (ALB) was replaced in spring 2009 by the FSV Henry B. Bigelow (HBB) as the main platform for NEFSC research surveys, including the spring and fall bottom trawl surveys. Calibration experiments to estimate these differences in fishing power between the vessels were conducted and peer-reviewed. Length-based calibration models were used to express 2009-2010 NEFSC indices in ALB units.
Several state survey indices were available to characterize the abundance of SNE/MA winter flounder. The Massachusetts Division of Marine Fisheries (MADMF) spring, Rhode Island Division of Fish and Wildlife (RIDFW) spring, University of Rhode Graduate School of Oceanography

(URIGSO), Connecticut Department of Environmental Protection (CTDEP) Long Island Sound Trawl Survey, and the New Jersey Division of Fish, Game and Wildlife (NJDFW) ocean and rivers research surveys provided indices of abundance at age used in the assessment. Numerous state recruitment surveys (MADMF, RIDFW, CTDEP, New York Department of Environmental Conservation (NYDEC), NJDFW, Delaware Division of Fish and Wildlife (DEDFW)) were also considered.

3. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series (integrating results from TOR-5), and estimate their uncertainty. Include area-swept biomass estimates. Investigate if implied survey gear or catchability estimates are reasonable. Include a historical retrospective analysis to allow a comparison with previous assessment results.

The 2011 SAW 52 assessment indicates that during 1981-1993, fishing mortality (fully recruited F, ages 4-5) varied between 0.61 (1982) and 0.95 (1993) and then decreased to 0.47 by 1999. Fishing mortality then increased to 0.70 by 2001, and has since decreased to 0.051 in 2010, generally tracking the decrease in fishery catch. SSB decreased from 20,100 mt in 1982 to a record low of 3,900 mt in 1993, and then increased to 8, 900 mt by 2000. SSB has varied between 4,500-8,000 mt during 2001-2009, and was 7,076 mt in 2010. Recruitment at age 1 decreased nearly continuously from 71.6 million age-1 fish in 1981 (1980 year class) to 7.5 million fish in 2002 (2001 year class). Recruitment has averaged 10.5 million during 2003-2010. The fishery selectivity pattern in the first time block (1981-1993) was estimated to be 0.01 at age 1, 0.24 at age 2, 0.75 at age 3, was fixed at 1.00 at age 4, was estimated at 1.00 at age 5, 0.99 at age 6, and 1.00 at age 7+. The pattern in the second time block (1994-2010) was estimated to be 0.01 at age 1, 0.19 at age 2, 0.70 at age 3, was fixed at 1.00 at age 4, was estimated at 0.97 at age 5, 0.89 at age 6, and 0.67 at age 7+.

The precision of the 2010 stock size at age, F at age and SSB was evaluated using MCMC techniques. There is an 80% probability that fully recruited F for ages 4-5 in 2010 was between 0.04 and 0.06. There is an 80% probability that SSB in 2010 was between 6,433 mt and 8,590 mt. Retrospective analysis for the 2003-2010 terminal years indicates retrospective error in fishing mortality (F) ranged from -38% in 2006 to -13% in 2009, retrospective error in SSB ranged from +42% in 2004 to +12% in 2009, and retrospective error in recruitment at age 1 (R) ranged from +78% in 2005 (2004 year class) to -11% in 2009 (2008 year class).

For the NEFSC Spring, Fall, and Winter surveys expressed as swept area numbers, aggregate survey catchability (q) was estimated at 0.126, 0.617, and 0.253, respectively. The other calibration surveys are of more limited geographic extent and were input in their original units, and therefore q estimates for those surveys ranged from 0.00001 (MADMF summer seine survey age 0 index) to 0.0017 (CTDEP trawl survey). A comparison between the results of the current assessment and the five previous assessments, or "historical retrospective," illustrates the underestimation of fishing mortality and overestimation of SSB that had been present between assessments since 1995. This pattern is in addition to the persistent "internal retrospective" that has been present in each of the assessments. The SDWG notes that the current assessment with assumed M = 0.3 is not consistent with those previous which assumed M = 0.2, and that much of the upward magnitude shift in numbers and biomass and downward shift in fishing mortality is due to this change.

4. Perform a sensitivity analysis which examines the impact of allocation of catch to stock areas on model performance (in TOR-3).

The SDWG interpretation of TOR4 is that the variance of the commercial landings due to the 1995 and later area-allocation scheme should be used as the basis for the magnitude of landings that might be lost or gained from the stock-specific assessments, and then perform an exercise to run the assessment model with those potential biases and report the results. The SDWG developed such an exercise using the 2008 GARM-III assessment data and ADAPT VPA model in an initial response to TOR4 and concluded that the application of a annually varying "bias-correction" in one direction in such an exercise provides stock size estimates and BRPs that scale up or down by about the same average magnitude as the gain or loss. After evaluation of the first exercise, the SDWG concluded that the calculated variance of the area-allocated commercial landings likely underestimates the true error. More work was done to estimate the error in the commercial landings due to misreporting of commercial landings to statistical area at allocation level A, the initial reporting level in mandatory Vessel Trip Reports (VTRs). The SDWG elected to update the exercise using the final SNE/MA assessment ASAP model, with an additional 5% PSE in commercial landings added to the currently estimated 0.4 to 4.5% over the 1995-2010 time series. This increased the average commercial landings PSE from 0.9% to 3.7%, and increased the overall catch PSE from 8% to 10%, ranging from 4.9% in 1992 to 23.7% in 2010. The catch in the final assessment model was increased and decreased by the annually varying PSE and models re-run to provide an additional measure of uncertainty of assessment estimates. As in the previous version of the exercise, the application of a annually varying "bias-correction" in one direction in such an exercise provides stock size estimates that scale up or down by about the same average magnitude as the gain or loss. For the final ASAP mode, fishing mortality on average changed by +/- 0.3%, and the range in 2010 F was 0.05 to 0.04, comparable to the MCMC estimate of uncertainty. SSB on average changed by +/- 9.0%, and the range in 2010 SSB was 6,500 to 7,600 mt, within the MCMC estimate of uncertainty.

5. Examine the effects of incorporating environmental factors in models of population dynamics (e.g., spring water temperatures in an environmentally-explicit stock recruitment function).

Winter flounder spawn in winter and early spring in estuaries along the mid-Atlantic, southern New England and Gulf of Maine, as well as in continental shelf waters on Georges Bank. In southern New England, Manderson (2008) found that overall recruitment was linked to spring temperatures, presumably by acting on larvae, settlement stage, and/or early juveniles. Further, Manderson (2008) found that young-of-the-abundance among 19 coastal nurseries became more synchronized in the early 1990's and argued that increased frequency of warm springs was creating coherence in early life stage dynamics among local populations.

The best fit environmentally-explicit stock recruitment relationship for the Southern New England stock predicted higher recruitment at lower winter air temperatures. The variable in the best model was Southern New England air temperature in January and February. The best environmentally-model provided a similar function to the standard model at mean environmental conditions, but importantly the predicted asymptotic recruitment was lower with the environmental model. The environmentally-explicit models support the hypothesis that increased temperatures during spawning and the early life history result in decreased recruitment in the SNE/MA stock. Work is *underway within the SDWG to incorporate environmentally-explicit stock-recruitment models into the NFT standard software used to fit stock-recruitment models and to perform projections of stock and fishery catch. However, this work has not been developed sufficiently to be made available for peer-review at this time (see new Research Recommendation 10).*

6. State the existing stock status definitions for "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, and F_{MSY}) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

FMSY, SSBMSY, and MSY BRPs from an external stock-recruitment model and proxy BRPs based on 40% MSP were estimated. For the final assessment model, the stock-recruitment model with a fixed value for steepness (h=0.61) was judged to fit best while providing feasible results. FMSY is estimated to be 0.290; SSBMSY is estimated to be 43,661 mt; MSY is estimated to be 11,728 mt; F40% is estimated to be 0.327; SSB40% is estimated to be 29,045 mt; MSY40% is estimated to be 8,903 mt.

7. Evaluate stock status (overfished and overfishing) with respect to the "new" BRPs (from TOR 6), and with respect to the existing BRPs (from a previous accepted peer review) whose values have been updated.

The Southern New England/Mid-Atlantic (SNE/MA) winter flounder stock complex was overfished but overfishing was not occurring in 2010. Fishing mortality (F) in 2010 was estimated to be 0.051, below FMSY = 0.290 (18% of FMSY) and below F40% = 0.327 (16% of F40%). SSB in 2010 was estimated to be 7,076 mt, about 16% of SSMSY= 43,661 mt and 24% of SSB40% = 29,045 mt.

8. Develop and apply analytical approaches and data that can be used for conducting single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs) under a set of alternative harvest scenarios. If the stock needs to be rebuilt, take that into account in these projections.

   a. Provide numerical short-term projections (3-5 yrs, or through the end of the rebuilding period, as appropriate). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions about the most important uncertainties in the assessment (e.g., terminal year abundance, variability in recruitment).

Catch of 842 mt in 2011 is projected to provide median F2011 = 0.100 and median SSB2011 = 9,177 mt. Projections at F = 0.000 in 2012-2014 indicate less than a 1% chance that the stock will rebuild to SSBMSY = 43,661 mt by 2014.

b. Take into consideration uncertainties in the assessment and the species biology to describe this stock's vulnerability (see "Appendix to the SAW TORs") to becoming or remaining overfished, and how this could affect the choice of ABC.

Uncertainties that were not accounted for by assessment and reference point models were evaluated using model diagnostics. Standard model diagnostics (e.g., residual analyses, retrospective analyses) were used for model validation. Vulnerabilities that were not accounted for by assessment and reference point models were evaluated using exploratory modeling, habitat observations and testing the influence of environmental factors on recruitment dynamics. Additional considerations of vulnerability and productivity are the implications of shifts in distribution, recruitment dynamics and increased natural mortality. Nye et al. (2009) found an annual increase in mean depth (0.8 m per year) of the winter flounder distribution, which may have productivity and vulnerability implications. Apparent decreases in estuarine spawning or shifts toward coastal spawning (e.g., DeCelles and Cadrin 2010) may also have implications for vulnerability (e.g., less availability to recreational fisheries) and productivity (less larval retention). Consumption of winter flounder by other fishes, birds and mammals may be increasing as these predator populations increase. A considerable source of additional vulnerability is the continued weak recruitment and low reproductive rate (e.g., recruits per spawner) of SNE/MA winter flounder. If weak recruitment and low reproductive rate continues, productivity and rebuilding of the stock will be less than projected. Stock-recruit modeling suggests that warm temperatures are having a negative effect on recruitment of SNE/MA winter flounder.

c. Develop plausible hypotheses (e.g., mixing among the three stocks) which might explain any conflicting trends in the data and undertake scenario analyses to evaluate the consequences of these alternate hypotheses on ABC determination.

The SDWG has initiated further research pursuing use of a more complex model (i.e., Stock Synthesis) to maintain separate fishery and survey catch for the three current stock units, while allowing a small amount (a few percent) of exchange between the stock units based on information from historical tagging. However, development of that research has not progressed sufficiently to be made available for peer review at this time.

9. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

Twelve of the previous 16 research recommendations have been addressed in full or in part. Four have not been addressed. Twelve new research recommendations have been developed by the SDWG for SAW52.

INTRODUCTION

Stock Structure

Winter flounder (*Pseudopleuronectes americanus*) is a demersal flatfish species commonly found in North Atlantic estuaries and on the continental shelf. The species is distributed between the Gulf of St. Lawrence, Canada and North Carolina, U.S., although it is not abundant south of Delaware Bay. Boundaries for four stock units were originally defined in the Atlantic States Marine Fisheries Commission (ASMFC) management plan (Howell et al. 1992): Gulf of Maine (GOM), Georges Bank (GBK), Southern New England (SNE; waters from coastal Massachusetts to eastern Long Island, New York), and Mid-Atlantic (MA; western Long Island, New York , New Jersey, and Delaware waters). A review of tagging studies for winter flounder for the 1995 SAW 21 assessment (Shepherd et al. 1996; NEFSC 1996) indicated that mixing has occurred among the Southern New England and Mid-Atlantic populations. Shepherd et al. (1996) noted that differences in growth and maturity among samples from Southern New England to the Mid-Atlantic could reflect discrete sampling along a gradient of changing growth and maturity rates over the range of a stock complex. Differences in growth rates within the Mid-Atlantic unit were observed to be greater than differences between Mid-Atlantic and Southern New England units (Shepherd et al. 1996). Therefore, since the 1995 SAW 21 assessment (NEFSC 1996), winter flounder populations in the Southern New England and Mid-Atlantic regions have been combined into a single stock complex for assessment purposes. Winter flounder in U.S waters are currently managed as three stock units: Gulf of Maine (GOM), Georges Bank (GBK), and Southern New England/Mid-Atlantic (SNE/MA; Figure A1). Within the SNE/MA stock complex, winter flounder undergo migrations from estuaries, where spawning occurs in the late winter and spring, to offshore shelf areas of less than 60 fathoms (110 meters).

Tagging studies (e.g., Howe and Coates 1975) indicate that there is limited mixing of fish among the three current stock units, with about 1%-3% between the GOM and SNE/MA, about 1% between GBK and SNE/MA, and <1% between GOM and GBK. Meristics studies based mainly on fin ray counts also indicate a separate GBK stock (Kendall 1912; Perlmutter 1947) or separate GOM, GBK, and SNE stocks (Lux et al. 1970; Pierce and Howe 1977). Growth and maturity studies also support the distinction of at least three stock areas (Lux et al. 1970; Howe and Coates 1975; Witherell and Burnett 1993), with GBK fish growing and maturing the fastest and GOM fish the slowest.

An interdisciplinary review of U.S. winter flounder stock structure was conducted for this assessment (DeCelles and Cadrin MS 2011). Information on morphology, tagging studies, genetics, larval dispersal, life history traits, environmental signals and meristics was considered. This work found “contingent groups” (localized populations) are likely present in several regions, and their coherence merits further research. Despite evidence for local population structure, information from tagging, meristics, and life history studies suggest extensive mixing within the current stock units, thereby supporting the current assessment and management structure.

The SNE/MA stock complex extends from the coastal shelf east of Provincetown, MA southward along the Great South Channel (separating Nantucket Shoals and Georges Bank) to the southern geographic limits of winter flounder off Delaware. Northeast Fisheries Science Center (NEFSC) commercial fishery statistical areas within this boundary are 521, 526, 533-539, and 611-639 (Figure A1). The corresponding recreational fishery areas are southern Massachusetts (the southern half of

Barnstable County; Dukes, Nantucket and Bristol counties), Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland and Virginia. NEFSC survey strata included for this stock extend from the waters of outer Cape Cod to the south and west, and include offshore strata 1-2, 5-6, 9-10, 25, 69-70 and 73-74 and inshore strata 2, 5, 8, 11, 14, 17, 20, 23, 26, 29, 45, 46 and 56.

Assessment History

The initial analytical assessment of the SNE/MA stock complex of winter flounder was completed in 1995 at SAW 21 (NEFSC 1996). The SAW 21 assessment included fishery catches through 1993, research survey abundance indices through 1995, catch at age analyzed by Virtual Population Analysis (VPA) for 1985-1993, and biological reference points based on Yield and Spawning Stock Biomass (SSB) per recruit models (Thompson and Bell 1934). The 1995 SAW 21 assessment concluded that the stock complex was over-exploited and at a record low level of SSB. SSB in 1993 was estimated to be 3,792 mt, about 11% of the Maximum Spawning Potential (MSP), and the fully recruited fishing mortality rate on ages 4-5 in 1993 was estimated to be F = 0.83, about four times F40% = 0.21.

The next benchmark assessment of the SNE/MA stock complex of winter flounder was completed in 1998 at SAW 28 (NEFSC 1999). The SAW 28 assessment included fishery catches through 1997, research survey abundance indices through 1998, catch at age analyzed by VPA for 1981-1997, and biological reference points based on a production model conditioned on VPA results. The 1998 SAW 28 assessment concluded that the stock complex was fully exploited and at a medium level of biomass. Total Stock Biomass (TSB) in 1997 was estimated to be 17,900 mt, about 64% of BMSY = 27,810 mt, and the fishing mortality rate on ages 4-5 in 1997 was estimated to be F = 0.31, just above F40% = 0.21, while the total biomass weighted F was 0.24, below FMSY = 0.37.

A benchmark assessment was completed in 2002 at SAW 36 (NEFSC 2003). The SAW 36 assessment included fishery catches through 2001, research survey abundance indices through 2002, and catch at age analyzed by VPA for 1981-2001. Biological reference points were based on stock-recruitment modeling conducted by the 2002 Working Group on Re-estimation of Biological Reference points for New England Groundfish (NEFSC 2002), which indicated that FMSY = 0.32, SSBMSY = 30,100 mt, and MSY = 10,600 mt. The SAW 36 assessment concluded that the stock complex was overfished and that overfishing was occurring. The SSB in 2001 was estimated to be 7,600 mt, about 25% of SSBMSY = 30,100 mt. The fishing mortality rate in 2001 was estimated to be F = 0.51, about 60% above FMSY = 0.32. The 2002 SAW 36 Review Panel noted that the 2002 assessment provided a much more pessimistic evaluation of stock status than the 1998 SAW 28 assessment, mainly due to the retrospective pattern of underestimation of F and overestimation of SSB during the late 1990s.

An updated assessment was completed in 2005 at GARM2 (NEFSC 2005). The GARM2 assessment included fishery catches through 2004, research survey abundance indices through 2005, catch at age analyzed by VPA for 1981-2004, and biological reference points based on the NEFSC (2002) stock-recruitment model. The 2005 GARM2 assessment concluded that the stock complex was overfished and that overfishing was occurring. The SSB in 2004 was estimated to be 3,938 mt, about 13% of SSBMSY= 30,100 mt. The fishing mortality rate in 2004 was estimated to be F = 0.38, about 19% above FMSY = 0.32. The GARM2 Review Panel noted that the VPA exhibited a severe retrospective pattern of underestimation of F and overestimation of SSB during the late 1990s and into 2001.

The most recent benchmark assessment was completed in 2008 at GARM-III (NEFSC 2008). The GARM-III assessment included fishery catch through 2007, research survey abundance indices through 2008, and catch at age analyzed by VPA for 1981-2007. The 2008 GARM-III Review Panel concluded that the "Base" VPA exhibited such a large retrospective pattern through the late 1990s and into 2001 that it required an adjustment. Splitting the time series of research survey data used in calibration was proposed to act as a proxy for fishery and biological factors that could have changed in the mid-1990s, resulting in the observed retrospective pattern. The VPA with most survey time series split at 1993/1994 appeared to reduce the retrospective pattern and this "Split" VPA was accepted as the best available estimate of stock status and a sufficient basis for management advice. Biological reference points were based on the non-parametric empirical Yield and SSB per recruit approach, which indicated that FMSY = F40% = 0.248, SSBMSY= SSB40% = 38,761 mt, and MSY = 9,742 mt. The 2008 GARM-III assessment concluded that the stock complex was overfished and that overfishing was occurring. The SSB in 2007 was estimated to be 3,368 mt, about 9% of SSBMSY= 38,761 mt. The fully recruited fishing mortality rate in 2007 was estimated to be F = 0.649, over twice FMSY= F40%= 0.248.

This 2011 SAW 52 benchmark assessment of the SNE/MA stock complex of winter flounder includes fishery and research survey catch through 2010.

Fisheries Management

Current management of the fisheries for winter flounder is coordinated by the Atlantic States Marine Fisheries Commission (ASMFC) in state waters and the New England Fishery Management Council (NEFMC) in federal waters. Winter flounder fisheries in state waters have been managed by Interstate Agreement under the auspices of the ASMFC Fishery Management Plan (FMP) for Inshore Stocks of Winter Flounder since 1992. The plan includes states from Delaware to Maine, with Delaware granted *de minimus* status (habitat regulations applicable but fishery management not required). Coastal states from New Jersey to New Hampshire have promulgated a broad suite of indirect catch and effort controls. State agencies have set minimum size limits for recreationally and commercially landed flounder, enacted limited recreational closures and bag limits, and instituted seasonal, areal, or state-wide commercial landings and fishing gear restrictions.

Winter flounder fisheries in the Exclusive Economic Zone (EEZ) are managed under the Northeast Multispecies Fishery FMP initially developed by the NEFMC in 1986. The principle catch of winter flounder in the EEZ has recently occurred as bycatch in directed trawl fisheries for Atlantic cod, haddock, and yellowtail flounder. The management unit encompasses the multispecies finfish fishery that operates from Maine through Southern New England. The FMP extends authority over vessels permitted under the FMP even while fishing in state waters if federal regulations are more restrictive than the state regulations. The initial FMP enacted codend minimum mesh size regulations, closed areas and seasons for haddock and yellowtail flounder, and an Exempted Fisheries Program allowing targeting of small-mesh species such as shrimp, dogfish, or whiting. In Southern New England waters, the groundfish bycatch on vessels fishing with small mesh was not limited in any way. There was an 11 inch (28 cm) minimum size for winter flounder which corresponded with the length at first capture (near zero percent retention) for 5.5 inch (140 mm) diamond mesh. Although the FMP was amended four times by 1991, it was widely recognized that many stocks, including winter flounder, were being overfished.

Time-specific stock rebuilding schedules were part of FMP Amendment 5 which took effect in May 1994. The rebuilding fishing mortality target for winter flounder was achievement of F20% within 10 years. Along with a moratorium on issuance of additional vessel permits, the cornerstone of Amendment 5 was an effort reduction program that required "large-mesh" groundfish vessels to limit their Days At Sea (DAS). There was an exemption from effort reduction requirements for vessels less than 45 feet in length and for "day boats." Vessels retaining more than the possession limit of groundfish (10% by weight, up to 500 lbs) were required to fish with either 5.5 inch (140 mm) diamond or square mesh in Southern New England or 6 inch (152 mm) mesh throughout the net in the regulated mesh area of Georges Bank-Gulf of Maine. The possession limit was allowed when using small mesh within the western Gulf of Maine (except for Jeffreys Ledge and Stellwagen Bank) and in Southern New England. Vessels fishing in the EEZ west of 72° 30' (the longitude of Shinnecock Inlet, NY) were required to abide by 5.5 inch (140 mm) diamond or 6 inch (152 mm) square codend mesh size restrictions consistent with the Summer Flounder FMP. The minimum landed size of winter flounder increased to 12 inches (30.5 cm), appropriate for the increased mesh size in order to reduce discards.

At the end of 1994, the NEFMC reacted to collapsed stocks of Atlantic cod, haddock, and yellowtail flounder on Georges Bank by recommending a number of emergency actions to tighten existing regulations to reduce fishing mortality. Prime fishing areas on Georges Bank (Areas I & II) and in the Nantucket Lightship Area were closed. The NEFMC also addressed an expected re-direction of fishing effort into Gulf of Maine and Southern New England waters while also developing Amendment 7 to the FMP. Under FMP Amendment 7, DAS controls were extended, and any fishing by an EEZ-permitted vessel required use of not less than 6 inch (152 mm) diamond or square mesh in Southern New England east of 72° 30'. Framework 27 in 1999 increased the square mesh minimum size to 6.5 inches (165 mm) in the Gulf of Maine, Georges Bank, and Southern New England mesh areas. FMP Amendment 9 revised the overfishing definitions for SNE/MA winter flounder as recommended by SAW 28 (NEFSC 1999).

During 2004-2009, formal rebuilding programs for many multispecies stocks, including winter flounder, were adopted to meet the requirements of the Magnuson-Stevens Act. The DAS allocations were reduced in 2004, 2006, and 2009 (FMP Amendment 13 and Framework 42). "Hard" (as opposed to target) quotas were adopted for a few programs and a few management units, although GBK yellowtail flounder was the only stock with a hard quota for all fishing.

The regulations of FMP Amendment 16 and Framework 44 were implemented in 2010, and the associated catch share program has resulted in most of the multispecies fishery being subject to hard quotas. A key component of the Amendment 16 catch share program was the formation of voluntary, self-selecting fishing organizations identified as "sectors." For SNE/MA winter flounder, Amendment 16 revised the overfishing definitions as recommended by the GARM-III (NEFSC 2008), established a target rebuilding date of 2014 under a target fishing mortality rate of F = 0.0, established an expected rebuilding date of 2017 given likely Fs, and specified Annual Catch Limits (ACLs) and Accountability Measures (AMs). Although the specified fishing mortality rate target for SNE/MA winter flounder for 2010-2012 is F = 0.0, and possession by federally permitted vessels is prohibited, the NEFMC and NMFS recognized that an incidental bycatch would be unavoidable. Framework 44 therefore established ACLs for SNE/MA winter flounder using the F expected to result from management measures designed to achieve F = 0.0, providing ACLs for the 2010-2012 Fishing Years (beginning May 1) of 605, 842, and 1125 metric tons.

Growth and Maturity

Winter flounder in the Gulf of Maine and Southern New England reach a maximum size of around 2.25 kg (5 pounds) and 60 cm. On Georges Bank fish may reach a maximum length of 70 cm and weight up to 3.6 kg (8 pounds; Bigelow and Schroeder 1953). An updated compilation and analysis of the NEFSC and Massachusetts Division of Marine Fisheries (MADMF) survey growth and maturity data for 1976-2010 for this assessment indicated the following maximum age, maximum length, and von Bertalanffy growth parameters that generally support the current stock structure (Figure A2):

GOM: 16,010 fish, maximum age 15 (55 cm); maximum length 61 cm;
Linfinity = 46.4 cm, k = 0.2727

GBK: 6,311 fish, maximum age 18 (50 cm), maximum length 70 cm;
Linfinity = 57.9 cm, k = 0.2829

SNE: 23,593 fish, maximum age 16 (51 cm), maximum length 60 cm;
Linfinity = 46.5 cm, k = 0.3184

The 1998 SAW 28 (NEFSC 1999) and previous assessments had used the maturity schedule as published in O=Brien et al. (1993) for winter flounder south of Cape Cod, based on data from the MADMF spring trawl survey for strata 11-21 (state waters east of Cape Cod, Nantucket sound, Vineyard Sound, and Buzzards Bay) sampled during 1985-1989 (n = 301 males, n = 398 females). Those data provided estimates of lengths and ages of 50% maturity of 29.0 cm and 3.3 yr for males, and 27.6 cm and 3.0 yr for females, and the following estimated proportions mature at age. The female schedule (with the proportion at age 2 rounded down to 0.00) was used in the SAW 28 assessment (NEFSC 1999).

Age	1	2	3	4	5	6	7+
Males	0.00	0.04	0.32	0.83	0.98	1.00	1.00
Females	0.00	0.06	0.53	0.95	1.00	1.00	1.00

In the 1998 SAW 28 review of the SNE/MA winter flounder stock assessment (NEFSC 1999), the SAW recommended re-examination of the maturity schedule used in the yield per recruit analysis (YPR) and VPA to incorporate any recent research results in the next assessment. In response to the SAW 28 recommendation, the 2002 SAW 36 (NEFSC 2003) examined NEFSC spring trawl survey data for the 1981-2001 period in an attempt to better characterize the maturity characteristics of the SNE/MA winter flounder stock complex. Data from the NEFSC survey included those judged in the SAW 28 assessment to comprise the SNE/MA complex from Delaware Bay to Nantucket Shoals: NEFSC offshore strata 1-12, 25 and 69-76, and inshore strata 1-29, 45-56. This was a much larger geographic area than that included in the MADMF survey data used in O=Brien et al. (1993). Data were analyzed in 5-6 year blocks (1981-1985, 1986-1990, 1991-1995, and 1996-2001) and for the entire time period (1981-2001), for each sex and combined sexes. Observed proportions mature at age were tabulated, and from those data maturity ogives at length and age were calculated to provide estimated proportions mature at age.

In general, the 2002 SAW 36 examination of the NEFSC maturity data indicated earlier maturity than the MADMF data, with L50% values ranging from 22-25 cm, rather than from 28-29 cm, and with ~50% maturity for age 2 fish, rather than ~50% maturity for age 3 fish. To investigate the apparent inconsistency between the MADMF and NEFSC maturity data, the two data sets were further compared over the same time periods (1985-1989, 1990-1995, 1996-2001) for common/adjacent survey strata (MADMF strata 11-12; NEFSC inshore strata 50-56 and offshore strata 10-12 and 25). For comparable time periods and geographic areas, the NEFSC maturity data still consistently indicated a smaller size and younger age of 50% maturity than the MADMF data. NEFSC L50% and A50% values ranged from 22-26 cm and about 2.0 yr, while the MADMF values ranged from 27-30 cm and about 3.0 yr. The difference in values from this comparison was not as large as for the full NEFSC data set extending southward to Delaware Bay, which incorporates components of the stock complex that mature at smaller sizes and younger ages. However, the difference was still nearly a full age class difference at 50% maturity.

Given that both length and age varied in the same direction, it seemed unlikely that the differences could be attributed to aging differences between the two data sets. Since the MADMF and NEFSC geographic areas in this comparison did not match exactly, the difference in maturity rates may have been due to the extension of the NEFSC strata to somewhat deeper waters inhabited by fish that mature at a smaller size and younger age (inclusion of fish in offshore strata were necessary for sufficient sample size). Alternatively, for the size range of fish in question (20 to 30 cm length), it might have been that immature and mature fish are segregated by area, with mature fish in that size interval tending to occupy inshore areas during the spring, with immature fish tending to remain offshore. Finally, there may have been differences in the accuracy and consistency of the interpretation of maturity stage between MADMF and NEFSC survey staff.

The 2002 SAW 36 considered these data and analyses and the possible causes for the noted inconsistencies, concluded that more detailed spatial and temporal analyses were needed before revisions to the maturity schedule could be adopted, and made a number of research recommendations for future winter flounder maturity work. The O'Brien et al. (1993) maturity at age schedule used in the 1998 SAW 28 and 2002 SAW 36 assessments was retained in the 2005 GARM 2 (NEFSC 2005), and 2008 GARM 3 (NEFSC 2008) assessments.

The 2002 SAW 36 assessment Research Recommendations were to "Evaluate the maturity at age of fish sampled in the NEFSC fall and winter surveys" and "Examine sources of the differences between NEFSC, MA and CT survey maturity (validity of evidence for smaller size or younger age at 50% maturity in the NEFSC data). Compare NEFSC inshore against offshore strata for differences in maturity. Compare confidence intervals for maturity ogives. Calculate annual ogives and investigate for progression of maturity changes over time. Examine maturity data from NEFSC strata on Nantucket Shoals and near George=s Bank separately from more inshore areas. Consider methods for combining maturity data from different survey programs."

Some of these 2002 SAW 36 research recommendations are addressed in this assessment. However, the NEFSC winter survey (1992-2007) age structures have not been processed, and so the associated maturity stages are not available in computerized form. Maturity data from the CTDEP trawl survey have not yet been compiled and provided in computerized form to the SDWG; therefore, no analyses have been completed for those data. The current work responding to the 2002 SAW 36 Research recommendations focuses on the maturity schedule for female fish, which in the past has been adopted as a proxy schedule for all the fish in the catch at age. In all cases, probit regression models assuming lognormal error were fit to the maturity data to estimate proportions mature at age. Both the MADMF and NEFSC maturity data have been recompiled and updated schedules computed.

The MADMF Spring survey data for the SNE/MA stock strata (11-21) were updated through 2008, with year blocks for 1982-1984, 1985-1989 (corresponding to the data subset included in the O'Brien [1993] maturity schedule), 1990-1995, 1996-2001, 2002-2007, 2008, and all data combined for 1982-2008. The MADMF maturity data indicate a consistent pattern over the time series, with maturity at age 2 less than 10% across the time series, and some increase in maturity at age 3 (from about 50% to about 66%) in the 2002-2007 period (Figure A3).

Figure A3 and the table below show that when all the currently available MADMF Spring female maturity data are combined (1982-2008; 8208 in the plot legend) the resulting schedule is within 2-3% at age of the O'Brien (1993) schedule used in previous assessments.

Age	1	2	3	4	5	6	7+
O'Brien 1993	0.00	0.06	0.53	0.95	1.00	1.00	1.00
Current	0.00	0.08	0.56	0.95	1.00	1.00	1.00

The NEFSC Spring survey data for all SNE/MA stock complex strata (offshore 1-12, 25, 69-76; inshore 1-26, 45-56) were also updated through 2008, with year blocks for 1981-1984, 1985-1989 (corresponding to the data subset included in the O'Brien [1993] maturity schedule), 1990-1995, 1996-2001, 2002-2007, and 2008. The NEFSC Spring maturity data indicate a more variable pattern over the time series than the MADMF Spring data, with maturity at age 2 ranging from 28% to 70% across the time series, and maturity at age 3 at greater than 90% for the entire 1981-2008 period. The NEFSC Spring data continue to indicate an age of 50% maturity (A50) of about age 2 (Figure A4), compared to A50 = age 3 for the MADMF Spring data.

Data from the NEFSC Fall survey, the NEFSC Spring survey for Massachusetts waters inshore strata (55-56; Nantucket Shoals), and the NEFSC Spring survey for Massachusetts waters offshore strata (9-12 and 25) have also been compiled and analyzed in the same way as the NEFSC Spring and MADMF Spring survey full data sets, to respond to the Research Recommendations. Like the NEFSC Spring data, the NEFSC Fall data indicate an age of 50% maturity (A50) of about age 2 (Figure A5), compared to A50 = age 3 for the MADMF Spring data. The NEFSC Spring Massachusetts waters inshore strata maturity data indicate a more variable pattern over the time series than the full NEFSC Spring data set, with maturity at age 2 ranging from 0% to 74% across the time series, and maturity at age 3 from 89% to 100%. Like the full NEFSC Spring data set, the NEFSC Spring Massachusetts inshore data indicate an age of 50% maturity (A50) of about age 2 (Figure A6), compared to A50 = age 3 for the MADMF Spring data. Finally, the NEFSC Spring Massachusetts waters offshore strata maturity data indicate a more variable pattern over the time series than the full NEFSC Spring data set, with maturity at age 2 ranging from 6% to 86% across the time series, and maturity at age 3 from 73% to 100%. Like the full NEFSC Spring data set, the NEFSC Spring Massachusetts Offshore data indicate an age of 50% maturity (A50) of about age 2 (Figure A7), compared to A50 = age 3 for the MADMF Spring data.

Given the respective characteristics of the MADMF Spring and various strata set combinations of the NEFSC Spring and Fall maturity, and the indications from the McBride et al. (MS 2011) histological work that age 2 fish are likely not mature, the SDWG concluded that the MADMF Spring survey data continue to provide the best macroscopic evaluation of the maturity stage for SNE/MA winter flounder. The SDWG recommended that the MADMF Spring data 1982-2008 maturity estimates at age (age 1 - 0%; age 2 – 8%; age 3 – 56%; age 4 – 95%, age 5 and older – 100%) be used in the 2011 SAW 52 assessment.

Instantaneous Natural Mortality (M)

The SDWG adopted a change in the instantaneous rate of natural mortality (M) for the winter flounder stocks. The value of M used in all previous assessments was 0.20 for all ages and years, and was based on the ICES/FAO 3/Tmax "rule-of-thumb" (e.g., see Vetter 1988 and Quinn and Deriso 1999) using observed maximum ages for winter flounder (Tmax) of about 15. The current observed Tmax values for the three stock units are GOM = 15 years, GBK = 18 years, and SNE/MA = 16 years (see Growth and Maturity section, above). The adopted change increases this rate to 0.30 for all stocks, ages and years. Evidence can be found in the literature and current model diagnostics to support the increase.

Literature values of M from tagging studies and life history equations indicate M for winter flounder is likely higher than 0.20. Dickie and McCracken (1955) carried out a tagging study in St. Mary Bay, Nova Scotia, Canada (GOM Stock) and estimated a percentage natural mortality rate to be 30% (M = 0.36). Saila et al. (1965) made equilibrium yield calculations for winter flounder from Rhode Island waters (Tmax = 12) using F values from Berry et al. (1965) and calculated M to be 0.36. Poole (1969) analyzed tagging data from New York waters from five different years and estimated values for M of 0.54 (1937), 0.33 (1938), 0.50 (1964), 0.52 (1965), and 0.52 (1966). Finally, an analysis of tagging data from a large scale study along the coast of Massachusetts provided a percentage natural mortality rate of 27%, or M = 0.32 (Howe and Coates 1975). For this assessment, a re-analysis of the Howe and Coates (1975) tagging data was conducted using a contemporary tagging model to estimate natural mortality (Wood MS 2011). The tagging model fit to the data was the instantaneous rates formulation of the Brownie et al. (1985) recovery model (Hoenig et al. 1998). This work provided an M of 0.30 with 95% confidence interval from 0.26 to 0.35.

Values derived from life history equations found in the fisheries literature also support a higher estimate of M for winter flounder. Three of these equations were used along with a maximum age (Tmax) of 16 to derive estimates of M equal to 0.28, 0.26, and 0.19 (the equations from Hoenig 1983, Hewett and Hoenig 2005, and the ICES/FAO "rule-of-thumb" respectively). A recently proposed method from Gislason et al. (2010), based on the SNE/MA stock mean length at age (Ages 1-16) and associated von Bertalanffy growth parameters from NEFSC survey 1976-2010 age-length data (see Growth and Maturity above), estimated M to be 0.37 (see text table below).

Values of Natural Mortality (M) for winter flounder found in the fisheries literature and derived using life-history equations.

Study	**Method**	**M**
ICES/FAO rule-of-thumb	Equation: 3/Tmax	0.19
Hewett and Hoenig 2005	Equation: 4.22/Tmax	0.26
Hoenig 1983	Equation: 1.44-0.982*ln(Tmax)	0.28
Howe and Coates 1975	Analysis of Tagging Data	0.32
Wood MS 2011	Re-analysis of Howe and Coates 1975	0.30
Poole 1969	Analysis of Tagging Data from 1938	0.33
Dickie and McCracken 1955	Analysis of Tagging Data	0.36
Saila et al. 1965	Ricker Equil. Yield Equation and Tmax	0.36
Gislason et al. 2010	Equation: Mean size at age and VBG	0.37
Poole 1969	Analysis of Tagging Data from 1964	0.50
Poole 1969	Analysis of Tagging Data from 1965	0.52
Poole 1969	Analysis of Tagging Data from 1966	0.52
Poole 1969	Analysis of Tagging Data from 1937	0.54

Preliminary assessment population model run diagnostics also in general support a higher value for M. Profiles of mean squared residual for Preliminary ADAPT VPA SNE/MA stock models indicate best fits for M in the range of 0.20 to 0.30. The likelihood profile of initial ASAP SCAA model runs for the SNE/MA stock indicates a best fit for M= 0.60 (Figure A8). Model runs from Rademeyer and Butterworth (MS 2011 a, b) SCAA (ASPM) models at M equal to 0.20, 0.30, and 0.40 also reveal decreasing negative log-likelihood as M is increased for GOM and SNE/MA stock models (see text tables below).

Results of SCAA for the Gulf of Maine winter flounder for each combination of 3 levels of natural mortality (*M*=0.2, 0.3 and 0.4, constant throughout the assessment period) and 3 weightings of the survey CAA likelihood (*w*=0.1, 0.3 and 0.5). The runs with w=0.3 and 0.5 have both commercial and survey selectivities flat at older ages, while the runs with w=0.1 have only the commercial selectivity flat. Displayed values are the negative log-likelihoods of each model.

	M		
Weighting	0.20	0.30	0.40
0.1	-123.2	-126.6	-129.1
0.3	-156.9	-177.2	-196.1
0.5	-255.6	-263.2	-280.8

Results of SCAA for the SNE/MA winter flounder for 3 levels of natural mortality for Base Case 2. Displayed values are the negative log-likelihoods of each model.

	M		
	0.20	0.30	0.40
-LL	-123.2	-126.6	-129.1

The SDWG also considered other evidence that might justify an increase in M for winter flounder. The NEFSC's food habits database (Smith and Link 2010) was examined to identify the major fish predators of winter flounder. These predators include Atlantic cod, sea raven, monkfish (goosefish), spiny dogfish, winter skate and little skate. A preliminary examination was undertaken to determine the prominence of winter flounder in the diets of these predators, across all seasons, years, size classes of predator, sizes of prey, and geographic locales. The overall frequency of occurrence of winter flounder in the stomachs is not a common or high occurrence (see text table below) and always less than 0.15%.

Occurrence of winter flounder in their major fish predators.

	Number of stomachs	Occurrences of winter flounder	% Freq. of occurrence
Spiny dogfish	67,565	27	0.040%
Winter skate	17,708	6	0.034%
Little skate	28,725	6	0.021%
Atlantic cod	20,142	27	0.134%
Sea raven	7,968	10	0.126%
Goosefish	10,742	12	0.112%

Further, the contribution of winter flounder to the diets of these predators species is also notably small (see text table below) and usually less than 0.4%.

Contribution of winter flounder (percent by weight) to the diet of their major fish predators.

	% Diet composition of winter flounder	
	L95% CI	U95%CI
Spiny dogfish	0.107%	0.205%
Winter skate	0.145%	0.160%
Little skate	0.012%	0.016%
Atlantic cod	0.240%	0.317%
Sea raven	0.784%	0.883%
Goosefish	0.249%	0.260%

Understandably the temptation exists to evaluate these relatively low contributions of diet with respect to consumptive removals of winter flounder as compared to winter flounder stock abundance and (relatively low) landings, initially using *ad hoc* or proxy methods. Yet just as one would not do so when assessing the status of a stock without a fuller exploration of all the sensitivities, uncertainties and caveats of the appropriate estimators and parameters, the SDWG did not recommend doing so for scoping winter flounder predatory removals at this time. The SDWG also noted that for percentages as low as observed, when allocated to the three winter flounder stocks and explored seasonally or as a time series, there are going to be large numbers of zeroes and attendant uncertainties and variances that would logically offset any potentially high individual predator total population-level consumption rates. Thus, the SDWG does not provide comment as to the merit of exploring or relative magnitude of the issue, but recommends that the topic should be forwarded as an important research recommendation.

Other sources of increased natural mortality may come from perceived increases in seal populations along the New England coast, which are known to be predators of winter flounder (Ampela 2009). Population size was estimated at 5,611 seals in 1999 (Waring et al. 2009) and a current survey is being conducted to estimate the size of the seal population. However, no time series of seal abundance or seal consumption of winter flounder are available.

TOR 1. Estimate catch from all sources including landings and discards. Characterize the uncertainty in these sources of data.

Landings

Commercial fishery landings reached an historical peak of 11,977 metric tons (mt) in 1966, then decreased through the 1970s, peaked again at 11,176 mt in 1981, and then steadily decreased to 2,128 mt in 1994. Commercial landings then increased to 4,556 mt in 2001 but have generally decreased since then. Under a prohibition of commercial possession in the EEZ since May 2009, commercial landings decreased to 271 mt in 2009 and 174 mt in 2010 (Table A1, Figure A9). Since 1995, the procedure used to allocate the commercial landings to statistical area has allowed estimation of the variance in the landings due to this process. For the SNE/MA winter flounder commercial fishery landings, the Proportional Standard Error (PSE) has averaged less than 1% (Table A1). About 66% of the commercial landings have been allocated to statistical area based on a match of Dealer records and Vessel Trip Reports for each trip over the 1995-2010 time series, with lesser percentages allocated based on an increasingly broad stratification basis (Table A2).

Most of the commercial landings from the SNE/MA stock complex have historically been taken from statistical areas 521 and 526 (east and south of Cape Cod, MA), 537 and 539 (south of Rhode Island), and 611-613 (Long Island Sound and south of Long Island; Table A3 and Figures A10-A13 for the years 1983, 1993, and 2000). With the restrictions on EEZ landings beginning in 2009, the percentage of landings from area 521 decreased from about 40% in 2007-2008 to about 20% in 2009; however, that percentage rebounded to 58% in 2010 (Table A3 and Figures A10, A14-A15). In 2009 about 40% of the commercial landings were from areas 537 and 539 off Narragansett Bay, RI, and about 35% off the coasts of NY and NJ. In 2010 about 18% of the commercial landings were from areas 537 and 539 off Narragansett Bay, RI, and about 12% off the coasts of NY and NJ. The primary gear used in the commercial fishery is the otter trawl, which has accounted for an average of 98% of the landings since 1989. Scallop dredges, hand-lines, pound nets, fyke nets, and gill nets account for the remaining 2% of total landings. Most SNE/MA winter flounder are landed as large and small market categories; additional, port-specific categories exist for medium, unclassified, and lemon sole (i.e., extra large and jumbo; Figure A16).

Recreational fishery landings in numbers and weight are directly estimated by the National Marine Fisheries Service (NMFS) Marine Recreational Fisheries Statistics Survey (MRFSS). Recreational landings peaked in 1984 at 5,510 mt, but declined substantially thereafter (Table A4, Figure A9). Recreational landings have been less than 1,000 mt since 1991, with only 28 mt estimated for 2010. The states of New York and New Jersey account for most of the recreational fishery landings (Figure A17), and the principal mode of fishing (>90%) is from private or rental boats, with most recreational landings occurring during January to June (Figure A18). The PSE of the recreational landings has averaged about 27% over the time series (Table A4).

Discards

In the review of the 1995 SAW 21 assessment of SNE/MA winter flounder (NEFSC 1996), the workshop concluded that there were too few NEFSC Fishery Observer Program sampled trips in which winter flounder were caught to adequately characterize the overall ratio of discards to landings in the commercial fishery. The Observer sample length frequency data, however, were judged adequate to help characterize the proportion discarded at length. Therefore, commercial discards for 1985 to 1993 were estimated from length frequency data from the NEFSC and MADMF trawl surveys, commercial port sampling of landings at length and Observer sampling of landings and discard at length. In this "mesh-selection" approach, survey length frequency data aggregated by half-years (MADMF survey in spring and NEFSC survey in fall, to maximize sample size) were smoothed using a three point moving average, then filtered through a mesh selection ogive for 4.5 inch (114 mm) mesh (1984-1989), 5.0 inch (127 mm) mesh (1990-1992, spring 1993) or 5.5 inch (140 mm) mesh (fall 1993). The choice of mesh sizes was based on the sizes and selection curves used in the yellowtail flounder assessments for southern New England (Rago et al. 1994) and comparison to length frequencies of commercial landings. The mesh filtering process resulted in a survey length frequency of retained winter flounder. A logistic regression was then used to model the percent discarded at length from 1989-1992 Observer data, and the resulting percentages at length were applied to the survey numbers at length to produce the survey-based equivalent of commercial kept and discarded winter flounder. The 1989-1992 average percentage discard at length was applied to 1981-1988. The survey numbers per tow at length "kept" were then regressed against commercial numbers landed at length. The linear relationship was calculated for those lengths common to both length frequencies and fitted with an intercept of zero. The slope of the regression provided a conversion factor to re-scale the survey "discard" numbers per tow at length to equivalent commercial numbers at length. The resulting vector of number of fish discarded at length was multiplied by a discard mortality rate of 50% (as averaged in Howell et al. 1992) to produce the vector of fish discarded dead at length per half year. The number of dead discards at length was adjusted by the ratio of weighout landings to total commercial landings and summed across seasons and lengths (and corresponding weight at length) to produce the annual total number and weight of commercial fishery discards for 1985-1993. In the SAW 28 assessment (NEFSC 1999), this same method using the 4.5 in mesh ogive and 1989-1992 average discard percentage at length was used to estimate commercial fishery discards for 1981-1984. These previously estimated values will be retained in the current assessment for estimates of the 1981-1993 commercial fishery discards (Table A5).

In the 1998 SAW 28 (NEFSC 1999), 2002 SAW 36 (NEFSC 2003), and 2005 GARM2 (NEFSC 2005) assessment, the SAW 21 survey length-mesh selection method, NEFSC Fishery Observer data (OB), NER

Vessel Trip Report (VTR), and Northeast Region Dealer Report (DLR) data were considered as sources of information to estimate commercial fishery discards, with a focus on the latter three sources. The characteristics of both the OB and VTR discard data (number of trip samples, frequency distributions of discards to landings ratio per trip, mean and variance of annual half-year discards to landings ratio) as a source for discard rates were examined, and the assessment reviews concluded that the VTR mean discard to landed ratio aggregated over all trips in annual half-year season strata (January to June, July to December) provided the most reliable data from which to estimate commercial fishery discards. VTR trawl gear fishery discards to landings ratios on a half-year basis (January to June; July to December) were applied to corresponding commercial fishery landings (all gears) to estimate discards in weight for 1994-2004. VTR discard ratios for winter flounder for other gears (scallop dredge, gillnet) were judged to be too variable to provide reliable estimates of discards.

In the 2008 GARM-III (NEFSC 2008) assessment, the Standardized Bycatch Reporting Method (SBRM) approach to the estimation of discards (Wigley et al. 2008) was applied for comparison with the OB and VTR discard rate estimation methods used in previous assessments. Discard rates by half-year were calculated for trawls and scallop dredges, and applied to the corresponding landings (winter flounder landings for the OB and VTR rates; landings of all species for the SBRM rates). OB discard rate estimates were found to be higher and more variable than discard estimates from the VTR and SBRM methods, which were generally of about the same order of magnitude. In particular, the 1999 and 2000 OB discard estimates appear to be infeasible.

When the VTR and SBRM discard estimates were examined by gear, it was apparent that the scallop dredge estimates generally made up a larger part of the SBRM estimate total when compared to the VTR estimates. The scallop dredge fishery lands a small amount of SNE/MA winter flounder (<35 mt annually) compared to the trawl fishery (1,000-5,000 mt annually, prior to 2009), and so even though the VTR scallop dredge discard rates can be high, the VTR discard estimates for the scallop fishery were relatively low. In previous assessments neither the OB nor VTR discard rate data were considered adequate for the estimation of discards specific to the scallop dredge fishery, due to sample size and inter-annual variability of the rates. In contrast, the SBRM scallop dredge discard estimates are quite variable and can be much larger than the trawl discard estimates, in spite of a low discard rate (discard of winter flounder to total landings of all species), because of the large magnitude of total fish landings in the fishery and the sensitivity of the discard estimate calculation to small inter-annual changes in the absolute discard rate. After reviewing the magnitude and precision of discard estimates from the VTR and SBRM approaches, the 2008 GARM-III panel adopted the SBRM as the best method for estimation of SNE/MA winter flounder commercial fishery discards for 1994 and later years. The PSE of the commercial discards has averaged 27% over the time series. A discard mortality rate of 50% was applied to the commercial live discard estimates, as assumed in Howell et al. (1992). Commercial fishery discard losses (i.e., dead fish) peaked in the early 1980s at 1,000-1,500 mt per year. Commercial fishery discard losses have since decreased to less than 200 mt per year since 1997 (Table A6).

Recreational fishery live discards in numbers of fish are directly estimated by the MRFSS (B2 category), and the estimated numeric variance has been assumed for the discard in weight, which is estimated in the assessment by allocation according to the length assumptions or samples. The PSE of the recreational discards has averaged 30% over the time series. A discard mortality rate of 15% was applied to recreational live discard estimates as assumed in Howell et al. (1992). Recreational fishery discard losses (i.e., dead fish) peaked in 1984-1985 at about 700,000-750,000 fish or 150-200 mt. Discard losses have since decreased to less than 100,000 fish or 20 mt per year since 2000. (Table A4).

Length and Age Sampling and Estimated Age Compositions

Length samples of winter flounder are available from both the commercial and recreational landings. In the commercial fishery, annual length sampling intensity varied from 10 to 251 mt landed per 100 lengths measured during 1981-2010 (Table A7). Port sampling has generally been adequate to develop the annual commercial fishery landings at age on a half-year or quarterly, market category basis (Table A8). In the recreational fishery, annual length sampling intensity varied from 28 to 614 mt landed per 100 lengths measured during 1981-2010 (Table A9). Recreational fishery ages were determined on a half-year basis using NEFSC survey spring and fall age-length keys.

As noted above, prior to 1994 the NEFSC trawl survey length frequencies and commercial trawl fishery mesh selection data were used to estimate the magnitude and characterize the length frequency of the commercial fishery discard. For 1994-2010, NEFSC Fishery Observer trawl and scallop fishery winter flounder discards to total all-species landings ratio estimates (SBRM approach) were applied to corresponding commercial fishery all-species landings to estimate discards . The NEFSC Fishery Observer length frequency samples were applied on a half-year basis to characterize the proportion discarded at length for 1994-2010 (Table A10). The ages of the commercial fishery discards were determined using NEFSC survey spring and fall age-length keys.

Irregular sampling of the recreational fisheries by state fisheries agencies since 1997 has indicated that the recreational fishery discard is usually of fish below the minimum landing size of 12 inches (30.5 cm). For 2002-2010, discard length samples from the NYDEC sampling of the recreational for-hire fishery and from the CTDEP Volunteer Angling Survey (VAS) have been used to better characterize the recreational fishery discard. Ages were determined on a half-year basis using NEFSC survey spring and fall age-length keys.

Commercial and recreational fishery landings and discards at age are presented in Tables A11-A14. Total fishery catches and mean weights at age are summarized in Tables A15-A16 and Figures A19-A20. Aggregate fishery catches in weight and numbers are summarized in Table A17.

TOR 2. Present survey data being considered and/or used in the assessment (e.g., regional indices of abundance, recruitment, state and other surveys, age-length data, etc.). Characterize uncertainty in these sources of data.

The NEFSC spring and fall bottom trawl surveys provide long time series of fishery-independent indices for SNE/MA winter flounder. The NEFSC spring and fall surveys are conducted annually during March-May and September-November, ranging from just south of Cape Hatteras, North Carolina north to Canadian waters (Figures A21-A22). The NEFSC winter surveys were conducted during 1992-2007 from Cape Hatteras north to Georges Bank. Stratified mean indices for the NEFSC spring, fall, and winter surveys are presented in Table A18 and Figure A23.

The Fisheries Survey Vessel (FSV) *Albatross IV* (ALB) was replaced in spring 2009 by the FSV *Henry B. Bigelow* (HBB) as the main platform for NEFSC research surveys, including the spring and fall bottom trawl surveys. The size, towing power, and fishing gear characteristics of the HBB are significantly different from the ALB, resulting in different fishing power and therefore different survey catchability. Calibration experiments to estimate these differences were conducted during 2008 (Brown 2009), and the results of those experiments were peer reviewed by a Panel of independent (non-NMFS) scientists during the summer of 2009 (Anonymous 2009, Miller et al. 2010). The terms of reference for the Panel were to review and evaluate the suite of statistical methods used to derive calibration factors by species before they were applied in a stock assessment context. Following the advice of the August 2009 Peer Review (Anonymous 2009), the all-seasons ratio estimator calibration factors were initially adopted to convert HBB survey catch number and weight indices to ALB equivalents. The aggregate catch number calibration factor for all seasons is 2.490; the aggregate catch weight factor for all seasons is 2.086.

The SDWG noted that the HBB will not routinely sampled the shallowest inshore strata in the standard set previously used for SNE/MA winter flounder (e.g. 47, 1, 3, 4, 12, 13, etc.), and also that winter flounder were rarely caught in the two deepest bands of offshore strata (e.g., 7-8, 11-12, etc.). The SDWG recommended that the NEFSC spring and fall survey time series be revised to reflect a strata set consistent with that being sampled by the HBB (i.e., using only the deepest band of inshore strata) and excluding the two deepest bands of offshore strata (i.e., generally consistent with the set used for the Winter survey series). The revised strata set includes offshore strata 1, 2, 5, 6, 9, 10, 25, 69, 70, 73, and 74, and inshore strata 2, 5, 8, 11, 14, 17, 20, 23, 26, 29, 45, 46, and 56, for the years 1976 and later.

Since the 2009 Peer Review, it has become evident that accounting for size of individuals can be important for many species. If there are different selection patterns for the two vessels for a given species, the ratio of the fractions of the fish caught by the two vessels can vary with size. Since 2009, length-based calibration factors have been estimated for several stocks (cod, haddock, and yellowtail flounder through the Trans-boundary Resource Assessment Committee [TRAC] assessment process; silver, offshore, and red hakes during the 2010 SARC 51 and *Loligo* squid during the 2010 SARC 51 (Brooks et al. 2010, NEFSC 2011). For those length-based calibrations, the same basic beta-binomial model from Miller et al. (2010) was assumed, but various functional forms were assumed for the relationship of length to the calibration factor. Since then, Miller (submitted) has explored two types of smoothers for the relationship of relative catch efficiency to length and the beta-binomial dispersion parameter. The smoothers (orthogonal polynomials and thin-plate regression splines) allow much more flexibility than the functional forms previously considered for other stocks by Brooks et al. (2010) and NEFSC (2011).

The SDWG reviewed work by Miller (MS 2011) on winter flounder in greater detail, and compared the model results for all winter flounder to those from a model that accounted for effects of stock area (GOM, GBK, and SNE/MA). The SDWG also explored seasonal effects, but did not fully pursue those models due to a lack of samples in the Gulf of Maine stock region during the spring. The lead assessment scientists for each of the winter flounder stocks compared predicted indices in Albatross units based on the different fitted models to explore the degree of consistency between calibrated indices using the different models.

When fitting the fourth order polynomial with smoother models to data from each stock region, there were convergence issues for the GOM stock data, likely due to over-parameterization of the length effects. When the order of the polynomial was reduced to two for this region, these issues were resolved. The resulting model performed better than the best models that Miller (submitted) fit that did not account for effects of stock area. Inspection of residuals revealed no strong trend with predicted number captured by the HBB or total number captured by station and no strong departure from normality. The predicted relative catch efficiency was lowest at intermediate size classes for all three stock areas, but the location of the minimum was at larger size for the GBK stock than for the other stock areas. For the SNE/MA stock, there were actually two minima with a slight rise in relative catch efficiency estimated between them.

When applying the relative catch efficiencies to surveys conducted in 2009 and 2010 with the HBB, there is an important caution to note. Lengths may be observed in these surveys that are outside of the range of lengths observed during the calibration study. This problem is exacerbated when the data are broken down into stock area subsets for the estimation of relative catch efficiency, because the limits of the range of sizes available in the subsets can be narrower than the range of the entire data set, and so caution must be taken in predicting catches in ALB units at these sizes. The SDWG also had some concerns with the asymptotically increasing estimates of relative catch efficiencies at the smallest and largest sizes for the winter flounder stocks, particularly when converting historic ALB indices to HBB equivalents. Sizes of fish outside of the ranges observed during the calibration study would potentially lead to extremely high HBB abundance indices at the extremes of the length composition for the historic data.

An adaptation of the regional model was explored that constrained lengths beyond a minimum and maximum length to have constant relative catch efficiencies. The minima and maxima were determined by specifying a maximum coefficient of variation (CV) of predicted relative catch efficiencies at these lengths. These CV criteria resulted in models that provided aggregate abundance indices that were very similar to the corresponding models without the CV criteria. Because no ad-hoc CV criteria were necessary in the initial regional length models, the SDWG found those to be preferable.

Lastly, the swept areas for each tow during the 2009 and 2010 surveys would ideally be used to predict ALB catches at each station, but if there is little variability in the swept areas, a mean can be used and the mean number per tow at length in HBB units can be converted to ALB units. The fourth order polynomial model fit to data for the SNE/MA stock region, incorporating a mean ratio of the vessel swept areas of 0.5868 (HBB to ALB), was used to calculate the factors at length (Figure A24) used to calibrate the 2009-2010 NEFSC HBB survey indices to ALB units for use in population model calibration (Table A19). After the application of age-length keys, the effective calibration factors at age (ratio of HBB to ALB indices at age) ranged from 6.86 at age 1 in spring 2009 to 2.50 at age 7+ in spring 2010, averaging 3.19 across all ages and seasons (Table A20).

Several state survey time series were available to characterize the abundance of SNE/MA winter flounder. The MADMF spring survey, Rhode Island Division of Fish and Wildlife (RIDFW) spring survey, University of Rhode Graduate School of Oceanography (URIGSO), Connecticut Department of Environmental Protection (CTDEP) Long Island Sound Trawl Survey (LISTS) spring, and the New Jersey Division of Fish, Game and Wildlife (NJDFW) ocean and rivers research survey trends are summarized in Tables A21-A22 and Figures A23 and A25. The numerous state recruitment surveys (MADMF, RIDFW, CTDEP, New York Department of Environmental Conservation (NYDEC), NJDFW, Delaware Division of Fish and Wildlife (DEDFW)) are summarized in Table A23 and Figures A26-A27.

The University of Rhode Island Graduate School of Oceanography (URIGSO) has conducted a standardized, two-station trawl survey in Narragansett Bay and Rhode Island Sound since the 1950s, with consistent sampling since 1963. The mean numbers per tow for the two stations, one in upper Narragansett Bay and one at the mouth of the Bay, were averaged to provide annual aggregate and indices at age. The URIGSO indices for SNE/MA winter flounder peaked in the late 1960s and again in the early 1980s, and have since shown has decreasing trend, with a record low in 2007 (Table A24 and Figure A25).

The VIMS NEAMAP industry-cooperative survey was started in fall 2006 to provide research survey samples in the spring and fall seasons along the Atlantic coast from Rhode Island to North Carolina in depths of 20-90 feet (9-43 meters). The NEAMAP indices for SNE/MA winter flounder do not indicate a trend in the recent abundance of winter flounder (Table A25 and Figure A25).

Indices at age are available from most of the research surveys for use in model calibration and are presented in Tables A26-A36.

TOR 3. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series (integrating results from TOR-5), and estimate their uncertainty. Include area-swept biomass estimates. Investigate if implied survey gear or catchability estimates are reasonable. Include a historical retrospective analysis to allow a comparison with previous assessment results.

2008 GARM-III ADAPT VPA Model selection process

The suite of research survey calibration indices developed for use in the 2002 SAW 36 assessment (NEFSC 2003) was retained in the 2005 GARM2 and 2008 GARM-III assessments (NEFSC 2005, 2008). The 2008 GARM-III VPA BASE case model exhibited a strong retrospective pattern, although it was less severe in the most recent terminal years than in the 2005 GARM2 assessment. Retrospective patterns in stock assessments result from structural errors in model, occurring when there has been a change during the model time series some inputs or estimated parameters that are assumed known (e.g., the catch) or constant (e.g., natural mortality or survey catchability). The 2008 GARM-III Panel (NEFSC 2008) considered that there are four potential causes of retrospective patterns in age structured stock assessments: 1) an unrecorded change in catches, 2) an undetected change in natural mortality, 3) an undetected change in survey calibration index catchability (q), or 4) an undetected change in fishery selectivity or partial recruitment. In all cases, either the biomass has changed (changes in natural mortality and unrecorded catch) or is perceived to have changed (changes in catchability or selectivity) in a way that cannot be explained by the catch-at-age data. Random noise is thought to be an unlikely cause of the retrospective pattern, based on simulation analyses considered by the 2008 GARM-III Panel, although those analyses raised the possibility of retrospective patterns being caused by mis-specification of the likelihood function or the impact of influential data points in the survey calibration series. The 2008 GARM-III Panel noted that while assuming dome-shaped fishery and survey partial recruitments may resolve retrospective patterns, these may also lead to what was termed “cryptic” biomass – biomass generated by the model that has not been observed in either the fishery or surveys. Throughout the 2008 GARM 3 review, the burden of proof was placed upon analysts to convincingly demonstrate that fish existed in the population when not observed in the fishery and surveys, even if the model fit with dome-shaped partial recruitment appeared superior. In some cases, additional information (data and/or assumptions) external to the model was considered (NEFSC 2008).

It was not possible to determine which single factor or combination of factors was responsible for the retrospective pattern observed in the SNE/MA winter flounder VPA model. However, the 2008 GARM-III

Panel judged that it was appropriate to adjust the model formulation to reduce the retrospective pattern (NEFSC 2008). In the SNE/MA winter flounder VPA model, the survey series were therefore split "pre and post 1994" (i.e., split between 1993 and 1994, given the change in commercial discard estimation and commercial landings reporting methods between these years), except for the NEFSC Winter, NJDFW Ocean, and NJDFW River survey series, which began in 1992, 1993, and 1995, respectively. Under this SPLIT run configuration, the retrospective pattern was reduced. No significant problems in residual patterns developed as a result of splitting the survey series, and the pattern for the NEFSC Fall survey appeared to be improved (less of a trend/blocking from negative residuals in the 1980s to positive residuals in the 1990s-2000s, likely corresponding to the change in retrospective patterns). There was little change in the pattern of the CTDEP Spring residuals, which continued to show a trend/ blocking in both the BASE and SPLIT run configurations. The precision of the SPLIT run terminal year estimates was comparable to the BASE run estimates. The Mohn's rho statistic calculated for the BASE and SPLIT runs ([retrospective year – terminal year]/terminal year; i.e., relative difference), either summed or averaged over the last seven retrospective years, was comparable in absolute magnitude but opposite in sign for F. The absolute value of the Mohn's rho for SSB was about 85% smaller for the SPLIT run; the value for recruitment at age 1 was about 30% smaller. The SPLIT configuration ADAPT VPA model was accepted as the basis for 2008 GARM-III SNE/MA winter flounder catch advice (NEFSC 2008).

2011 SAW 52 input data and Preliminary model configurations and results with M = 0.2

An initial population analysis was conducted using the NOAA Fisheries Toolbox (NFT) ADAPT VPA version 3.0.3. (NFT 2010) to provide a "bridge" from the 2008 GARM-III assessment (NEFSC 2008) to the current work by demonstrating updated results using the same general model configuration. The following NEFSC and state agency trawl survey abundance indices at age were input as candidate calibration indices: NEFSC spring trawl ages 1-7+, NEFSC fall trawl ages 1-6+ (advanced to calibrate January 1 abundance of ages 2-7+), NEFSC winter trawl ages 1-5, MADMF spring trawl ages 1-7+, RIDFW fall seine age 0 (advanced to age-1), RIDFW spring trawl ages 1-7+, URIGSO trawl ages 1-7+, CTDEP fall seine age 0 (advanced to age-1), CTDEP spring trawl ages 1-7+, NYDEC trawl age 0 (advanced to age-1) and ages 1-2, MADMF summer seine index of age-0 (advanced to age-1), DEDFW juvenile trawl age-0 (advanced to age-1), NJDFW Ocean trawl ages 1-7+, and NJDFW River trawl ages 1-7+ (Tables A26-A36). In all models, the NEFSC Winter, Spring and Fall indices were input as "area-swept" numbers (assuming 100% survey efficiency and area-swept of 0.0112 square nautical miles per tow). Both BASE (with all survey indices input as continuous series) and SPLIT (with some survey series split at 1993/1994, as in the 2008 GARM-III assessment) preliminary ADAPT VPA model configurations were considered.

As an alternative to the ADAPT VPA model used in the 2008 GARM-III assessment (NEFSC 2008), the same input catch and survey index data were used in the ASAP version 2.0.21 Statistical Catch At Age (SCAA) model (NFT 2011). Two model configurations of the survey calibration indices were constructed. In the first, Indices At Age (IAA), the survey indices were input as in the ADAPT VPA, with each index at age input as a separate series with a fixed selectivity at age of one (S = 1) and a characteristic Coefficient of Variation (CV) set at 0.4 (40%). In this configuration, a catchability coefficient (q) is estimated for each index at age; the CV of the q was set at 0.9 to allow flexibility from the starting value, and the weighting factor (Lambda) for each index at age was set equal to one (L = 1). Annual Effective Sample Sizes (ESS) for the fishery age compositions was set at 200. An internal stock-recruitment relationship was not estimated. Both BASE and SPLIT model ASAP IAA configurations were considered.

In the second ASAP configuration, the survey indices were input as the aggregate total and as a vector of indices at age for each year. In this configuration, each set of survey indices at age is modeled as a multinomial distribution (probabilities at age; MULTI) with an accompanying vector of fixed or estimated of selectivity at age, with the CV of selectivity set at 0.5. To ensure robust estimation, the selectivity was fix at one (S=1) for age 4, and selectivity at age estimated for the other ages in each series. A characteristic CV for each series aggregate total was set at 0.4 (40%). The CV of the catchability coefficient (*q*) for each series was set at 0.9 to allow flexibility from the starting value, and the weighting factor (Lambda) for each index series was set equal to one (L = 1). Annual Effective Sample Sizes (ESS) for the fishery age compositions was set at 200; annual ESS for all multinomial survey age compositions was set at 10. For single age recruitment index series, the surveys were modeled as in the IAA configuration. An internal stock-recruitment relationship was not estimated. Both BASE and SPLIT model ASAP MULTI configurations were considered.

The Preliminary ADAPT VPA BASE model run with M = 0.2 provided estimates of SSB that ranged from about 17,000 mt in 1982 to 2,300 mt in 2005, increasing to 4,200 mt in 2010. Estimates of F (ages 4-5) increased from about 0.54 in 1981 to 1.55 in 1993, decreasing to 0.09 in 2010. Recruitment at age 1 ranged from about 61 million in 1981 (1980 year class) to about 4 million in 2007 (2006 year class). The preliminary VPA BASE run exhibited a strong retrospective pattern, with the underestimation of terminal F ranging from -53% in terminal year 2005 to -29% for terminal years 2008-2009 and the overestimation of SSB ranging from +103% in 2007 to +30% in 2009.

The Preliminary ADAPT VPA SPLIT model run with M = 0.2 provided estimates of SSB that ranged from about 17,000 mt in 1982 to 1,900 mt in 2009, increasing to 2,900 mt in 2010. Estimates of F (ages 4-5) increased from 0.54 in 1981 to 1.55 in 1993, decreasing to 0.14 in 2010. Recruitment at age 1 ranged from about 61 million in 1981 (1980 year class) to about 3 million in 2007 (2006 year class). The SPLIT configuration resulted in a reduced retrospective pattern compared to the BASE run, with the retrospective error in terminal F ranging from -26% in terminal year 2005 to +16% for terminal year 2006 and the retrospective error in SSB ranging from +57% in 2007 to +6% in 2009.

Estimates from the Preliminary ADAPT VPA SPLIT model run with M = 0.2 are compared with previous assessment results in Figures A28-A30. In general, the historical trends in F and recruitment are very similar, but "historical retrospective" errors in both estimates are evident. Historical estimates of SSB during 1981-1985 are the most different in absolute terms; these differences are due mainly to changes in the ADAPT VPA calculations for the oldest true age, the "plus-group" age 7+, and the use of the exact catch equation (instead of Pope's approximation) in the current ADAPT VPA model, compared to versions used in previous assessments. Substantial "historical retrospective" errors in SSB are also evident for the 1997, 2001, 2005, and 2007 terminal years.

In the Preliminary ADAPT VPA SPLIT run configuration with M = 0.2, the retrospective pattern was reduced as the estimated survey catchability (*q*) generally decreased before the split (1981-1993) and increased after (1994-2010), by as much as +/- 40%-50% (e.g., NEFSC Fall survey). For several series (e.g., NEFSC Spring and Fall, RI Spring) the pattern in *q* at age also became more asymptotic (flat) after the split (Figure A31). For the CT Spring series, however, the changes were different, from a nearly flat pattern in the BASE configuration to one with a decreasing trend in *q* at age before the split at 1993/1994 but an increasing trend in *q* at age after in the SPLIT configuration (Figure A31). For the NJ and URIGSO series changes in survey *q* were small (Figure A32). Of the YOY series, the largest proportional changes in *q* were in the MA and CT indices, generally following the pattern of reduced *q* before the split and increased *q* after the split (Figure A32). In the VPA, there was little change in the fishery selectivity patterns between the BASE and SPLIT configuration with both exhibiting a decrease on selectivity at ages 2-4 during 1994-2010, in line with expectations given changes in fisheries regulations (Figure A33).

The Preliminary ASAP IAA BASE model run with M = 0.2 provided estimates of SSB that ranged from about 11,500 mt in 1982 to 2,100 mt in 1993, increasing to 4,800 mt in 2000, and then decreasing again to 2,100 mt in 2008 before increasing to 3,600 mt in 2010. Estimates of F (ages 4-5) increased from 0.67 in 1982 to 1.32 in 1985 and then remained at about 0.6 or higher until peaking again at 1.14 in 2007, before decreasing to 0.08 in 2010. Recruitment at age 1 ranged from about 55 million in 1981 (1980 year class) to about 5 million in 2007. The ASAP IAA fishery selectivity patterns before and after the survey split (the runs were purposely configured with fishery selectivity blocks to coincide with the survey split) were similar to those from the VPA, but with a slight dome for the years before the split (1981-1993) at age 6-7+ (S = 0.7-0.8; Figure A33). The ASAP IAA BASE run exhibited a moderate retrospective pattern, with the underestimation of terminal F ranging from -65% in terminal year 2007 to -16% for terminal year 2009 and the overestimation of SSB ranging from +73% in 2007 to +8% in 2009.

The Preliminary ASAP IAA SPLIT model run with M = 0.2 provided estimates of SSB that ranged from about 15,000 mt in 1982 to 2,000 mt in 1993, increasing to 3,900 mt in 2000, and then decreasing again to 1,600 mt in 2008 before increasing to 2,600 mt in 2010. Estimates of F (ages 4-5) increased from 0.57 in 1982 to 1.22 in 1985 and then remained at about 0.6 or higher until peaking again at 1.22 in 2007, before decreasing to 0.12 in 2010. Recruitment at age 1 ranged from about 66 million in 1981 (1980 year class) to about 4 million in 2007 (2006 year class). The SPLIT configuration resulted in a reduced retrospective pattern compared to the BASE run, with the retrospective error in terminal F ranging from -55% in terminal year 2007 to -2% for terminal year 2008 and the retrospective error in SSB ranging from +56% in 2007 to 0% in 2008. The SDWG noted that the reduction in the retrospective pattern due to the SPLIT configuration was not as great for the ASAP IAA model as for the ADAPT VPA.

In the ASAP IAA SPLIT run configuration, the retrospective pattern was reduced as the estimated survey catchability (*q*), as in the ADAPT VPA SPLIT run, generally decreased before the split (1981-1993) and increased after (1994-2010), by about the same as in the VPA (e.g., NEFSC Fall survey; Figure A34). For several series (e.g., NEFSC Spring and Fall, RI Spring) the pattern in *q* at age also became slightly more asymptotic (flat) after the split (Figure A34). For the CT Spring series, however, the changes were again different, from a nearly flat pattern in the BASE configuration to one with a decreasing trend in *q* at age before the split but an increasing trend in q at age after in the SPLIT run; however, the changes were smaller than in the VPA (Figures A32, A34).

For the NJ and URIGSO series, there were only small changes in survey q. Of the YOY series, as in the VPA the largest proportional changes in *q* were in the MA and CT indices, generally following the pattern of reduced *q* before the split and increased *q* after the split. In the ASAP IAA SPLIT run, there was more of a change in the fishery selectivity patterns between the BASE and SPLIT configuration than in the VPA, with an increase in selectivity at ages 6-7+ during 1994-2010 (Figure A33).

The Preliminary ASAP MULTI BASE model run with M = 0.2 provided estimates of SSB that ranged from about 15,000 mt in 1983 to 3,400 mt in 1994, increasing to 7,100 mt in 2000, and then decreasing again to

4,300 mt in 2005 before increasing to 6,400 mt in 2010. Estimates of F (ages 4-5) increased from 0.73 in 1982 to 1.12 in 1991 and then decreased to 0.07 in 2010. Recruitment at age 1 ranged from about 66 million in 1981 (1980 year class) to about 5 million in 2003 (2002 year class). The ASAP MULTI BASE fishery selectivity pattern before the survey split (the runs were purposely configured with fishery selectivity blocks to coincide with the survey split) was similar to those from the VPA and ASAP IAA models. The ASAP MULTI BASE fishery selectivity pattern after the split (1994-2010) was different, however, with a more substantially domed shape and S ~ 0.6-0.8 at age 6 and ~0.2-0.4 at age 7+ (Figure A33). The ASAP MULTI BASE run exhibited a moderate retrospective pattern, with the underestimation of terminal F ranging from -35% in terminal year 2003 to -13% for terminal year 2009 and the overestimation of SSB ranging from +48% in 2007 to +12% in 2009.

The Preliminary ASAP MULTI SPLIT model run with M = 0.2 provided estimates of SSB that ranged from about 15,000 mt in 1983 to 3,000 mt in 1994, increasing to 6,200 mt in 2000, and then decreasing again to 2,000 mt in 2009 before increasing to 3,800 mt in 2010. Estimates of F (ages 4-5) were consistently high, from 0.74 in 1982 to 1.17 in 1991, remaining above 0.6 until 2007, and then decreasing to 0.09 in 2010. Recruitment at age 1 ranged from about 67 million in 1981 (1980 year class) to about 4 million in 2007 (2006 year class). The SPLIT configuration resulted in a very slightly reduced retrospective pattern compared to the BASE run, with the retrospective error in terminal F ranging from -38% in terminal year 2006 to -16% for terminal year 2009 and the retrospective error in SSB ranging from +56% in 2007 to +18% in 2008. In contrast to the ADAPT VPA and ASAP IAA models, the use of the SPLIT configuration in the ASAP MULTI run configuration was not effective in reducing the retrospective errors, and in fact the errors were generally larger for most of the terminal year "peels."

In the ASAP MULTI SPLIT run configuration, the estimated aggregate survey catchability (*q*), as in the ADAPT VPA and ASAP IAA SPLIT runs, generally decreased before the split (1981-1993) and increased after (1994-2010), but generally by less for most surveys (in relative terms) than the age-specific *q* in the VPA or ASAP IAA models (e.g., NEFSC Fall survey; Figure A35). More response was seen in the ASAP MULTI runs in the estimated survey and fishery selectivity patterns. In general, survey selectivity patterns were more asymptotic (flat) after the split (Figure A36), while the fishery selectivity pattern after the split became "less-domed" by about 10% for age 5, 30% for age 6 and 50% for age 7+ (Figure A33).

A second ASAP MULTI SPLIT run configuration (SELEX3) included a third fishery selectivity block, for the years 2006-2010, as a means to explore the sensitivity of the ASAP model retrospective patterns. The SELEX3 configuration resulted in nearly the same retrospective pattern as the MULTI SPLIT run with 2 fishery selection blocks run; the retrospective error in terminal F ranged from -35% in terminal years 2006-2007 to -17% for terminal year 2009 and the retrospective error in SSB ranged from +49% in 2007 to 12% in 2008. Therefore, adding a third selectivity block to the ASAP MULTI SPLIT model did not further reduce the retrospective pattern.

A third ASAP MULTI SPLIT run (S7P) was configured to explore the sensitivity of the model to fixing the fishery selectivity at age 7+ at S = 0.8, in line with the results from the ADAPT VPA and ASAP IAA models. Fixing S = 0.8 for age 7+ resulted in little change in fishery selectivity pattern at ages 5-6 between the two time blocks, and minor changes in the model population and F estimates.

The S7P configuration resulted in nearly the same retrospective pattern as the MULTI SPLIT run with estimated fishery selectivity for age 7+; the retrospective error in terminal F ranged from -38% in terminal year 2006 to -18% for terminal year 2009 and the retrospective error in SSB ranged from +52% in 2007 to +19% in 2009. Therefore, fixing the selectivity of age 7+ at S = 0.8 had little effect on either the model estimates or the retrospective pattern.

A comparison of these Preliminary ADAPT VPA and ASAP BASE and SPLIT configuration model results with M = 0.2 is presented in Figures A37-A39 for Fishing Mortality, SSB, and recruitment at age 1. Time series patterns in F were in general similar for the six model configurations, although annual estimates varied by as much as 2-3 fold (e.g., 2007), due mainly to differences in the estimated fishery selectivity patterns among models. Trends in SSB were likewise comparable, again with as much as a 2-3 fold difference. Trends in recruitment at age were the most consistent, with the greatest variation at the beginning of the time series.

2011 SAW 52 Developmental model configurations and results with M = 0.3

Besides providing a "bridge" back to the 2008 GARM-III assessment results, examination of the Preliminary ADAPT and ASAP model runs with M = 0.2 clarified the changes in survey *q* (both aggregate and at-age), survey selectivity, and fishery selectivity that occurred with different model configurations (i.e., BASE versus SPLIT; ASAP IAA versus ASAP MULTI). The SDWG elected to continue model development with the ADAPT VPA and ASAP MULTI models, dropping the ASAP IAA configuration from further consideration, since the MULTI configuration provided increased model flexibility (ability to weight and estimate both survey selectivity and aggregate catchability, and to weight fishery catch components) and was generally more in line with widely accepted Statistical Catch at Age (SCAA) modeling practice. The ADAPT VPA SPLIT configuration was carried forward since the retrospective pattern was reduced compared to the BASE configuration, which was dropped from further consideration. However, the ASAP MULTI BASE configuration was carried forward, since the SPLIT configuration was not effective in reducing the retrospective in the ASAP model.

All available survey indices had been used in the calibration in the Preliminary runs (see previous section). In the subsequent model development process, the SDWG reviewed the performance of survey indices used in the calibration and removed some indices from the models based on based on consideration of a) the partial variance in an initial VPA trial run including all indices, b) the precision of the survey series, c) residual error patterns from the various trial runs, and d) the significance of the correlation among indices and with ADAPT VPA abundance estimates from the preliminary BASE run configuration including all potential calibration indices. The SDWG discussed the relative merits of including all available indices in the models versus excluding some indices at age from multi-age time series due to poor performance, typically those at the youngest and oldest ages. The SDWG concluded that all age groups for multi-age surveys would be included in further Developmental models, with the exception of the NYDEC Peconic Bay Small Mesh Trawl Survey (Table A33), for which none of the indices exhibited acceptable diagnostics.

The following single age, YOY abundance indices were also excluded from Developmental model runs because of the presence of large partial variances (i.e., lack of fit), lack of correlation with model estimates, or trends in the residuals (i.e., indication of bias): RIDFW seine survey age 0 (advanced to age 1), NYDEC index of age-0 (advanced to age-1), and DEDFW juvenile trawl age-0 (advanced to age-1; Table A23).

The next step in model development was to increase M from 0.2 to 0.3, adopt the revised calibration survey set in the models, and investigate the Developmental ADAPT VPA SPLIT and ASAP MULTI BASE model estimates and diagnostics. Time series in trends in F, SSB, and R were comparable for the VPA SPLIT M = 0.2, VPA SPLIT M = 0.3, and ASAP MULTI BASE M = 0.3 models. Increasing M in the VPA decreased the estimates of F and increased the estimates of SSB and R. The ASAP model estimates of F were about 25% lower over the time series than from the VPA with M = 0.2, and were higher at the start of the time series and lower since the late 1980s (Figure A40). ASAP model estimates of SSB averaged about 25% higher, and were lower at the start of the time series and higher since the late 1980s (Figure A41). ASAP recruitment estimates at age 1 averaged about 50% higher than the VPA with M = 0.2 for most of the time series (Figure A42). The range of retrospective errors in F and SSB from the VPA with M = 0.3 were comparable to the VPA with M = 0.2, with no "patterns" in F (Figures A43-A44). The ASAP model exhibited a retrospective pattern on underestimation of F and overestimation of SSB, with the range of retrospective errors in F and SSB (about 40%) comparable to but slightly less than those from the VPA models (40-50%) (Figure A45).

The next developmental step was the further investigation of configurations that would reduce the retrospective errors in the ASAP MULTI model, through changes in the weighting of likelihood components and selection of survey calibration indices. Five additional ASAP models were configured: a) reducing the weight on the fishery catch compositions from 200 to 50, still 5 times that for the survey age compositions, b) reducing the on the fishery catch compositions from 200 to 10, equal to that for the survey age compositions, c) fixing the fishery selectivity in both periods (1981-1993; 1994-2010) at S = 1.0 (flat topped) for ages 4 and older, d) removal from the model of the NEFSC Fall survey series, which exhibited a strong residual pattern in most model configurations and e) internal estimation of the stock-recruitment function. Of these configurations, reducing the annual fishery ESS from 200 to 10 (ASAP model CAT10) provided decreased retrospective errors in both F (ranging from -38% to -13%) and SSB (ranging +42% to +12%), and so this ESS setting was adopted for subsequent ASAP model development.

The SDWG noted that sensitivity run e) internal estimation of the stock-recruitment function, provided feasible estimates of steepness (h = 0.66) and reference points when using a steepness prior. However, the final model did not include internal stock-recruitment function estimation; instead, the stock-recruitment parameters were fit externally so that a consistent set of mean weights (most recent 5 year average) could be used in the calculation of FMSY and potential proxies, to ensure consistency with biomass reference point and fishery catch projections.

In addition to the ADAPT VPA and ASAP MULTI Developmental models, Rademeyer and Butterworth (MS 2011b) provided an implementation of an Age-Structured Production Model (ASPM), in which they explored approaches to the reduce the retrospective errors in the SNE/MA assessment. Rademeyer and Butterworth (MS 2011b) implemented both autocorrelation in survey q variability and a "ramped" increase in M over time (10% per year across all ages, from 1995-2005, increasing M from 0.3 in 1995 to 0.6 in 2005 and later years). This configuration in the ASPM greatly reduced the retrospective in SSB and R (Figure A46). Due to the combination of University of Cape Town (Republic of South Africa) intellectual property and NMFS policy issues, however, the Rademeyer and Butterworth (MS 2011b) ASPM model was not eligible to be used as the final assessment model.

The concept of an increasing trend in M over the assessment time series was incorporated into the ADAPT VPA and ASAP BASE models in several configurations, with the goal of reducing the retrospective patterns. The autocorrelation in *q*, however, was not able to be incorporated in ASAP in the time available, as it would require programming changes. The change in M in the ADAPT VPA and ASAP models was incorporated both as a “ramp” of 10% per year from 0.3 to 0.45 or 0.6, beginning in 1994 or 2000, and as a “step” in M from 0.3 to 0.45 and from 0.3 to 0.6 in the year 2000. The retrospective errors observed for each of these model configurations are summarized and compared with the ADAPT VPA and ASAP SPLIT survey configurations with comparable values of M for all ages and years in Table A37. Incorporation of the “ramps” and “steps” in M in the BASE model configurations was effective in reducing the retrospective errors from 40-50% in the ADAPT VPA SPLIT models to 25-35% in ADAPT VPA BASE models. For the ASAP models, the range retrospective errors were reduced from over 50% to 13-18% (Table A37).

Based on these results and diagnostics, along with the inspection of residual patterns, the SDWG adopted the ASAP MULTI BASE model configuration CAT10 as the preferred model to move forward for further consideration, as it provided a more advanced and flexible model when compared to ADAPT VPA. The SDWG had extensive discussions about the implications of incorporating either a “ramp” or “step” in M to 0.6 in final models used for estimation of reference points and status determination, and concluded that based on analogy to the VPA SPLIT survey model configuration, the “step” approach was a better alternative. The SDWG elected to provide the ASAP CAT10 configuration (MULTI survey configuration, BASE survey *q* configuration, annual fishery ESS = 10, annual survey ESS = 10, M = 0.3 for all years and ages, no internal stock-recruitment function estimation) as the preferred final, or “best,” model for status determination. The retrospective pattern in this model is moderate, but comparable to that deemed acceptable in the 2008 GARM-III assessment (NEFSC 2008). The SDWG has also brought forward a model incorporating a “step” from M = 0.3 during 1981-1999 to M = 0.6 in 2000-2010 (the STEPM model) as an alternative that provides reduced retrospective errors, but that also provides a substantially different perception of stock productivity, or “state of nature,” for SNE/MA winter flounder in 2010 and beyond if M = 0.6 is assumed in the future.

The three model configurations were carried through the calculation of reference points and calculation of Frebuild and ABCs for 2012, although the results of the STEPM model are presented in less detail in subsequent portions of this report. The trends in F, SSB, and R for the preferred CAT10 model and the alternative STEPM model are compared in Figures A47-A49. The STEPM model provides lower estimates of F during the mid-1990s and early 2000s and higher estimates of F since 2006, and higher estimates of SSB during the mid-1990s and early 2000s and lower estimates of SSB since 2005. The STEPM model provides higher estimates of recruitment at age 1 throughout the assessment time series.

2011 SAW52 Final Assessment Model and Results

The ASAP CAT10 model configuration serves as the basis for evaluating the status of the stock and providing catch advice. The assessment indicates that during 1981-1993, fishing mortality (F ages 4-5) varied between 0.61 (1982) and 0.95 (1993) and then decreased to 0.47 by 1999. Fishing mortality then increased to 0.70 by 2001, and has since decreased to 0.051 in 2010, generally tracking the decrease in fishery catch (Table A38, Figure A50). SSB decreased from 20,100 mt in 1982 to a record low of 3,900 mt in 1993, and then increased to 8,900 mt by 2000. SSB has varied between 4,500-8,000 mt during 2001-2009, and was 7,076 mt in 2010 (Table A38, Figure A51). Recruitment at age 1 decreased nearly continuously from 71.6 million age-1 fish in 1981 (1980 year class) to 7.5 million fish in 2002 (2001 year class).

Recruitment has averaged 10.5 million during 2003-2010 (Table A38, Figure A51). The fishery selectivity pattern in the first time block (1981-1993) was estimated to be 0.01 at age 1, 0.24 at age 2, 0.75 at age 3, was fixed at 1.00 at age 4, was estimated at 1.00 at age 5, 0.99 at age 6, and 1.00 at age 7+. The pattern in the second time block (1994-2010) was estimated to be 0.01 at age 1, 0.19 at age 2, 0.70 at age 3, was fixed at 1.00 at age 4, was estimated at 0.97 at age 5, 0.89 at age 6, and 0.67 at age 7+.

The precision of the 2010 fishing mortality (F ages 4-5) and SSB was evaluated using MCMC techniques. One thousand MCMC iterations were realized (200,000 calculations with a thinning rate of 200). There is an 80% probability that F ages 4-5 in 2010 was between 0.04 and 0.06 (Figure A52). There is an 80% probability that SSB in 2010 was between 6,433 mt and 8,590 mt (Figure A53).

Retrospective analysis for the 2003-2010 terminal years indicates retrospective error in fishing mortality (F) ranged from -38% in 2006 to -13% in 2009, retrospective error in SSB ranged from +42% in 2004 to +12% in 2009, and retrospective error in recruitment at age 1 (R) ranged from +78% in 2005 (2004 year class) to -11% in 2009 (2008 year class; Figures A54-A56).

Model fits to the aggregate survey indices (for those with multinomial age compositions) and recruitment indices are provided in Figures A57-A60. For the NEFSC Spring, Fall, and Winter surveys expressed as swept area numbers, aggregate survey catchability (*q*) was estimated at 0.126, 0.617, and 0.253, respectively. The other calibration surveys are of more limited geographic extent and were input in their original units, and therefore *q* estimates for those surveys ranged from 0.00001 (MADMF summer seine survey age 0 index) to 0.0017 (CTDEP spring trawl survey). Fishery age composition simple residuals (observed minus predicted proportions at age) are presented in Figure A61. There are some large positive residuals (about 15% in real terms) early in the time series, and some large negative residuals (10-15% in real terms) early in the time series at ages 2 and 4, and again in 2010 at age 3. However, there were no problematic, extensive “runs” of large residuals evident for the fishery catch proportions at age.

A comparison between the results of the current assessment and the five previous assessments is presented in Figures A62-A64. This “historical retrospective” illustrates the underestimation of fishing mortality and overestimation of SSB that has been present between assessments since 1995. This pattern is in addition to the persistent “internal retrospective” that has been present in each of the assessments. The SDWG notes that the current assessment with assumed M = 0.3 is not consistent with those previous which assumed M = 0.2, and that much of the upward magnitude shift in numbers and biomass and downward shift in fishing mortality is due to this change.

TOR 4. Perform a sensitivity analysis which examines the impact of allocation of catch to stock areas on model performance (in TOR-3).

The SDWG interpretation of TOR4 is that the variance of the commercial landings due to the 1995 and later area-allocation scheme should be used as the basis for the magnitude of landings that might be lost or gained from the stock-specific assessments as a result of the allocation, and then perform an exercise to run the assessment model with those potential biases and report the results. For the SNE/MA stock the total catch consists of 4 components. The commercial landings have a calculated Proportional Standard Error (PSE; due to the aforementioned commercial landings area-allocation procedure; available for 1995 and later years, with the mean of those years substituted for 1981-1994) ranging from <1% to about 7%; the commercial discard PSEs range from 17-35% (available for 1994-2010, mean of those years substituted for 1981-1993); the recreational landings PSEs range from 17-40%; and the recreational discard PSEs range from 18-57%.

Because the PSEs for the commercial landings are low, and the commercial landings account for about two-thirds of the total catch, the total catch weighted-average annual PSEs range from 3.1-21.3%, and average 8% (un-weighted over years) for the 1981-2010 time series. The SDWG developed such an exercise using the 2008 GARM-III assessment data and ADAPT VPA model in an initial response to TOR4 and concluded that the application of a annually varying "bias-correction" in one direction in such an exercise provides stock size estimates and BRPs that scale up or down by about the same average magnitude as the gain or loss (Terceiro MS 2011a).

Since the initial exercise, the SDWG concluded that the calculated variance of the area-allocated commercial landings likely underestimates the true error. More work was done to estimate the error in the commercial landings due to misreporting of commercial landings to statistical area at allocation level A, the initial reporting level in mandatory Vessel Trip Reports (VTRs; Palmer and Wigley MS 2011). Vessel monitoring system (VMS) positional data from northeast United States fisheries for 2004-2008 were used to validate the statistical area fished and stock allocation of commercial landings derived from the VTRs. The accuracy of the VMS method relative to the VTRs was assessed using haul locations and catch data recorded by at-sea NEFSC Fishery Observers. This work was performed for several New England groundfish species. The perceived under-reporting of statistical areas in the VTR data led to minor (< 5%) differences in the overall species allocations; only nine stocks in the five year time-series exhibited differences in stock allocations exceeding 2.0% (2004: northern and southern silver hake, ± 3.0%; 2006: northern and southern windowpane flounder, ± 4.7%; 2007: Georges Bank winter flounder, 2.4%; 2008: Georges Bank winter flounder, 2.4%, Southern New England/Mid-Atlantic winter flounder, -3.2%, and northern and southern windowpane flounder, ± 3.4%).

Given the magnitude of these errors, the SDWG elected to update the exercise using the final SNE/MA assessment ASAP model, with an additional 5% PSE in commercial landings added to the currently estimated 0.4 to 4.5% over the 1995-2010 time series. This increased the average commercial landings PSE from 0.9% to 3.7%, and increased the overall catch PSE from 8% to 10%, ranging from 4.9% in 1992 to 23.7% in 2010. The catch in the final assessment model was increased and decreased by the annually varying PSE and the adjusted models run to provide an additional measure of uncertainty of assessment estimates. As in the previous version of the exercise, the application of a annually varying "bias-correction" in one direction in such an exercise provides stock size estimates that scale up or down by about the same average magnitude as the gain or loss. For the final ASAP CAT10 model, fishing mortality on average changed by +/- 0.3%, and the range in 2010 F was 0.04 to 0.05, comparable to the MCMC estimate of uncertainty. SSB on average changed by +/- 9.0%, and the range in 2010 SSB was 6,500 to 7,600 mt, within the MCMC estimate of uncertainty (Figure A65).

TOR 5. Examine the effects of incorporating environmental factors in models of population dynamics (e.g., spring water temperatures in an environmentally-explicit stock recruitment function).

For the full presentation of the SDWG response to this TOR see Hare MS 2011 (SDWG52 WP13).

Winter flounder spawn in winter and early spring in estuaries along the mid-Atlantic, southern New England and Gulf of Maine coasts, as well as in continental shelf waters on Georges Bank (Able and Fahay 2010). There is also recent evidence of more coastal spawning in both Southern New England (Wuenschel et al. 2009) and in the Gulf of Maine (Fairchild et al. 2010). In southern New England, Manderson (2008) found that overall recruitment was linked to spring temperatures, presumably by acting on larvae, settlement stage, and/or early juveniles. Further, Manderson (2008) found that young-of-the-abundance among 19 coastal nurseries became more synchronized in the early 1990's and argued that increased frequency of warm springs was creating coherence in early life stage dynamics among local populations.

The specific mechanism linking temperature to recruitment was not defined by Manderson (2008), but temperature is an important parameter in many ecological processes affecting winter flounder. In a mesocosm study, Keller and Klein-MacPhee (2000) found that winter flounder egg survival, percent hatch, time to hatch, and initial size were significantly greater in cool mesocosms. Further, mortality rates were lower in cool mesocosms and related to the abundance of active predators. In the laboratory, Taylor and Collie (2003) found that consumption rates of sand shrimp were lower at lower temperatures implying lower predation pressure at colder temperatures. In the field, Stoner et al. (2001) found that settlement stage winter flounder prefer colder waters and that the importance of temperature in defining juvenile habitat decreases through ontogeny. Thus, temperature has multiple effects on the early life history of winter flounder and colder temperatures in general lead to higher survival and recruitment.

The relationship between winter flounder recruitment and temperature identified by Manderson (2008) did not include the effect of population size. The relationship between stock size and subsequent recruitment is generally poor in marine fishes (Rothschild 1986) but can have explanatory power. To examine the combined effect of environment and spawning stock biomass on recruitment, the goal here was to develop environmentally-explicit stock-recruitment relationships that include temperature and related environmental variables for the three U.S. stocks of winter flounder. As a basic framework, the approach of Hare et al. (2010) was followed. The resulting models could be used in short-term forecasts based on fishing and temperature scenarios (fixed patterns of temperature variability over several years) and long-term forecasts based on fishing and temperature projections from general circulation models.

To develop environmentally-explicit stock-recruitment relationships, three specific types of data are required: spawning stock biomass, recruitment, and environmental data. For the SNE/MA stock, recruitment (lagged by 1 year) and spawning stock biomass pairs were used from the ASAP CAT10 model (Table A38). Two general types of temperature data were used: air temperatures and coastal water temperatures (Table A39). Air temperature data from the NCEP/NCAR reanalysis (Kalnay et al. 1996) were used. This product combines observations and an atmospheric model to produce an even grid of atmospheric variables, in our case monthly mean surface air temperature. The spatial resolution is 2.5^{o} latitude by 2.5^{o} longitude. Air temperatures are closely related to estuarine water temperatures owing to efficient heat exchange in the shallow systems (Roelofs and Bumpus 1953, Hettler and Chester 1982, Hare and Able 2007). Data from representative grid points were averaged for each of three regions, and the monthly/regional averages were further averaged into annual estimates for three, two monthly periods (January-February, March-April, May-June).

Coastal water temperature data from Woods Hole, Massachusetts and Boothbay Harbor, Maine were available; the Woods Hole data were used for SNE/MA stock analyses (see Nixon et al. 2004 and Lazzari 1997 respectively). Monthly means were calculated from mostly daily data. These monthly means were then averaged into annual estimates for the three, two monthly periods (January-February, March-April, May-June). Temperature data were analyzed as annual averages for three, two month periods (January-February, March-April, May-June). These two monthly periods capture temperature variability from the late winter, through spring and into early summer. The spring period was identified as important by Manderson (2008). The broader seasonal range was chosen because of potential differences in the timing of winter flounder spawning and development among the three stocks (Able and Fahay 2010) and the uncertainty as to the stage where recruitment is determined.

In addition to temperature, four large-scale forcing indices were included in the analyses. The North Atlantic Oscillation (NAO) is the dominant mode of winter climate variability in the North Atlantic region and has been related to numerous physical and biological variables across the North Atlantic (Ottersen et al. 2001, Visbeck et al. 2003). Brodziak and O'Brien (2005) identified a significant effect of NAO on recruit-spawner anomalies of winter flounder in the Gulf of Maine. The mechanism is unspecified, but NAO is related to estuarine water temperatures in the region (Hare and Able 2007). The winter NAO index is used here (Hurrell and Deser 2010). The Atlantic Multidecadal Oscillation (AMO) is a natural mode of climate variability and represents a detrended multi-decadal pattern of sea surface temperatures across the North Atlantic with a period of 60-80 years (Kerr 2005). Nye et al. (2009) found the AMO was strongly related to distribution shifts of fishes in the northeast U.S. shelf ecosystem. Finally, the Gulf Stream index is a measure of the northern extent of the Gulf Stream south of the northeast U.S. shelf ecosystem. The Gulf Stream position is related to the larger basin-wide circulation, which in turn is related to NAO and AMO. Work by Nye et al. (in review) shows the Gulf Stream index has explanatory power for the distribution of silver hake in the system, possibly through the large-scale linkages between the Gulf Stream, Labrador Current and hydrographic conditions on the northeast U.S. shelf. Two Gulf Stream indices are used here (Joyce and Zhang 2010 and Taylor and Stephens 1998). The two indices differ in their calculation, with the Joyce and Zhang (2010) index more associated with the Gulf Stream south of the northeast U.S. shelf and the Taylor and Stephens (1998) index more associated with the Gulf Stream across the North Atlantic. For all four large-scale forcing indices, annual values were obtained. Numerous studies have found lagged effects of the NAO on the northeast U.S. shelf ecosystem (Greene and Pershing 2003, Hare and Kane in press). In particular, a two year lag has been related to the remote forcing of the NAO on the northeast U.S. shelf through the Labrador Current system. In addition, a zero year lag has been related to direct atmospheric forcing on the northeast U.S. shelf. Zero, one, and two year lags of were included for NAO and zero year lags were used for the other three large-scale forcing variables. To understand the relations between the 21 environmental variables, a simple correlation matrix was calculated. Significant correlations were considered in the context of previous research in the region. Significance was based on standard p-values; no corrections for multiple comparisons were made. The purpose was exploratory with an aim of understanding the relation between variables before incorporating them into stock recruitment functions.

Ricker, Beverton-Holt, and Cushing stock recruitment models were used with and without the different environmental terms. The model forms followed Levi et al. (2003), who built upon the ideas of Neill et al. (1994) and Iles and Beverton (1998). The fits of the three standard models were all very similar for the SNE/MA stock. Owing to the general acceptance of the Beverton-Holt model for use in stock-recruitment relationships and the overall similarity in the fits of the three models, here only the analyses using the Beverton-Holt model are presented. Environmental variables were assigned *a priori* for consideration with specific stocks. This was done to limit the number of environmentally-explicit stock recruitment relationships considered for each stock.

The standard stock-recruitment relationships were calculated first using the lsqcurvefit function in MatLab using the trust-region-reflective algorithm. A series of environmentally-explicit models also were fit using the same methods. The resulting models were compared using AICc and AICc weights, which represent the relative weight of evidence in favor of a model. The best environmentally-explicit model also was compared to the standard stock recruitment model using an evidence of weights procedure (Burnham and Anderson 1998). In this way the value of the environmentally-explicit stock recruitment functions relative to standard stock recruitment functions was judged. Model fitting included bounded parameters (or priors) to force realistic model forms.

Numerous relationships between environmental variables were evident based on the correlation analysis. The two Gulf Stream indices were related (r=0.54) but different enough to retain both in the analyses. Both Gulf Stream indices were related to the NAO with a 2 year lag (NAO leading). This relationship has been described before (Taylor and Stephens 1998). The Atlantic Multidecadal Oscillation exhibited relatively little relationship with other variables. The North Atlantic Oscillation was related to the two Gulf Stream indices as already noted. NAO was not related to winter temperatures which may result from non-stationarity in the NAO-winter temperature relationship (Joyce 2002). Woods Hole temperature is closely related to regional air temperatures. This link is not surprising based on previous studies. There is evidence of seasonal correlation in Woods Hole temperature, with values in January and February correlated to values in March and April, which in turn are correlated to values in May and June. However, the seasonal correlation is diminished after two months; temperatures in January and February are less related to temperatures in May and June.

The three air temperature series were all closely related indicating coherent air temperatures over the entire region. These analyses agree with the more comprehensive results of Joyce (2002). Correlations among regions over the same time (Jan-Feb) were higher than correlations within region between times (Gulf of Maine Jan-Feb compared to Gulf of Maine Mar-Apr). Seasonal correlation (Jan-Feb to Mar-Apr) were lower in the air temperature series compared to the water temperatures series as expected from the greater specific heat capacity of water.

The analyses suggest that the environmental forcing experienced by the three stocks differs in several important elements. The SNE/MA stock experiences coastal water temperatures that are strongly linked to local air temperatures. The GBK stock experiences water temperatures that are affected by both local air temperatures and more importantly, large-scale advective supply of relative cold, fresh water associated with the Labrador Current. Finally, the temperatures experienced by the GOM stock remain uncertain. If the Boothbay Harbor data is representative, then temperature is related to large-scale processes (AMO) and not local processes (air temperature). On the other hand, air temperature may be important, if early stage winter flounder are using shallower habitats.

Spawning stock biomass is comparable between the SNE/MA and GBK stock but recruitment is approximately four times greater for the SNE/MA stock at higher stock sizes (Figure A66). The stock recruitment functions for the GBK and GOM stock are similar, with near constant recruitment over a relatively broad range of spawning stock biomasses. Recruitment on Georges Bank is estimated to be higher than in the Gulf of Maine at a given spawning stock biomass.

The residuals of the stock-recruitment relationships for the three stocks appear to exhibit synchrony through time (Figure A67). Early in the time series, residuals between the stocks appear unrelated, but all residuals were positive in the mid 1990s and all were negative in the early 2000s. A formal analysis was conducted using serial correlation: calculating the correlation coefficient between two variables using a moving window. A similar analysis was used by Joyce (2002) to show that the relationship between NAO and east coast air temperatures has changed over the last 80 years and by Hare and Kane (in press) to show that the correlation between NAO and *Calanus finmarchicus* abundance has changed over the last twenty years. The serial correlation analysis demonstrated that early in the time series the residuals of the stock-recruitment functions were negatively or not correlated between the stocks (Figure A68). Then, during the early 1990s, the residuals became positively correlated. The trend is most evident for the SNE/MA and GOM stocks and less so for these two stocks compared to the GBK stock.

The timing in the synchrony between the SNE/MA and GOM stocks is similar to the timing in synchrony among local populations within the SNE/MA stock (Manderson 2008). This synchrony suggests that some large-scale forcing is responsible for creating variance in the stock recruitment relationships of winter flounder across the northeast U.S. shelf ecosystem. The synchrony is greater between the SNE/MA and GOM stocks suggesting that the large-scale forcing has greater coherence along the coastal areas of the northeast compared to the offshore waters of Georges Bank.

The best fit environmentally-explicit stock recruitment relationship for the Southern New England stock predicted higher recruitment at lower winter air temperatures (Table A40, Figure A69). The variable in the best model was Southern New England air temperature in January and February. This model had an evidence ratio of 106 compared to the standard model and explained an additional 14% of the variance (Table A41). Several other environmental variables were included in the top ten models (AMO, GS-J, and WH-JF), but three of the four top models included winter air temperatures over Southern New England. The best environmentally-model provided a similar function to the standard model at mean environmental conditions, but importantly the predicted asymptotic recruitment was lower with the environmental model.

The environmentally-explicit models support the hypothesis that increased temperatures during spawning and the early life history result in decreased recruitment in the SNE/MA stock. Winter temperature is correlated with spring temperature providing a potential bridge between this study and that of Manderson (2008). Using the same serial correlation approach to examine trends in winter air temperature shows an increase in correlation among the three regions starting in the late-1980's early-1990's. The correlation coefficients of Southern New England and Gulf of Maine air temperatures are correlated with the similar coefficients for recruitment. This result suggests that as regional air temperatures have become more coherent, winter flounder recruitment in the coastal stocks also has become more coherent.

To consider these environmentally explicit models stock recruitment models in the context of reference points, it is necessary to summarize model parameters. For the SNE/MA stock, an important issue in the standard stock recruitment model is the perceived need to bound the model parameters in both the prior stock assessment (NEFSC 2008) and in the current assessment. Specifically, the standard model estimates a high asymptotic recruitment (Table A42). Bounding asymptotic recruitment to the mean observed in a series of high recruitment years results in a very different model. At the mean environmental conditions, the unbounded environmentally-explicit model has a lower asymptotic recruitment (Table A42) and one benefit of this model is the lack of need for bounded parameters.

Another potential benefit for the environmentally explicit models is to forecast recruitment under different environmental conditions. Over the assessment record, there has been no change in winter air temperature (Figure A70). Further, the ability to forecast winter air temperatures in the 1-5 year range is limited at best. There is some skill in statistical seasonal forecasts with several months lead time (Cohen and Fletcher 2007) and developing forecast skill on the decadal scale is a major topic of research in the climate modeling community (Smith et al. 2007, Keenlyside et al. 2008), but interannual forecasts with demonstrated skill are few. Thus, the environmental models developed here can be used with a mean environment to calculate reference points. Additionally, scenarios could be evaluated calculating reference points under an assumption of warm winters and an assumption of cool winters to better inform management in the short-term.

The results of the analyses support Manderson's (2008) earlier finding. Recruitment in coastal stocks of winter flounder is related to temperature during the spawning season. Importantly, recruitment is also dependent on spawning stock biomass and the environmentally-explicit stock-recruitment models capture the combined effect of environment and stock size. The temperature effect is strongest in the Southern New England stock, where the species is at the southern extent of its range. The signal is less pronounced in the Gulf of Maine, but recruitment is still linked to winter temperatures. The effect of environment on recruitment of Georges Bank winter flounder is less clear. There is a lot of variability in the stock-recruitment relationship and none of this variability is explained with the environmental terms considered here. Whether other environmental factors play a role in Georges Bank winter flounder recruitment is an important question requiring future research.

The closer link to air temperatures for the Southern New England stock is explained by the argument that water temperatures in estuarine winter flounder spawning, larval, and juvenile habitats are more closely related to air temperature than to coastal water temperatures. Prior studies have found a close link between air temperature and estuarine water temperature (Hare and Able 2007). Future studies should explicitly treat the spatial dynamics of winter flounder in more detail (see Manderson 2008); such an approach could better examine the effect of environmental forcing on local populations.

One use of the environmentally-explicit models is to develop short-term and long-term forecasting models. Based on the above analyses, there is no trend in winter temperature over the past 30 years and thus short-term forecasts can be developed using the environmentally-explicit models assuming winter temperatures to be at their mean state. It may also be useful to develop short-term forecasts under warm temperatures and short temperatures to provide managers with a tangible understanding of the effect of temperature on the stocks. The environmentally-explicit models could also be used to develop longer-term forecasts following the approach of Hare et al. (2010). These forecasts would provide an assessment of the sustainability of the winter flounder fishery on the 30-100 year time scale.

Work is underway within the SDWG to incorporate environmentally-explicit stock-recruitment models into the standard NFT software used to fit stock-recruitment models and to perform stock and fishery projections. However, this work has not been developed sufficiently to be made available for peer-review at this time (see new Research Recommendation 10).

TOR 6. State the existing stock status definitions for "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, and F_{MSY}) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

In addition to the SNE/MA stock results presented below, the SDWG developed a unified response to TOR6 taking into consideration the assessment results for all three stocks, as presented in SDWG Working Paper D. As defined in the Magnuson Act, "overfishing" means "a rate or level of fishing mortality that jeopardizes the capacity of a fishery to produce the maximum sustainable yield on a continuing basis" (i.e., FMSY). The guidelines allow for the projected catch associated with the overfishing limit (OFL) to be based on FSMY proxies. Many proxies are used to define overfishing in situations when FMSY is not well determined. The SDWG interpreted these guidelines to mean that best practice is to use a FMSY estimate instead of a proxy if FSMY can be reliably estimated. The SDWG therefore estimated FSMY as well as proxies in the form of F40%. The SDWG developed consensus on some aspects of the FMSY estimates in terms of their relative magnitude across stocks, but also had some disagreement about the reliability of FMSY estimates that were related to the perceived reliability of the respective assessments. The SDWG could not come to consensus on the preferred reference points, and updated estimates of F40% were provided as the existing overfishing definitions and as alternatives to FMSY and SSBMSY estimates. Estimates of F40% and SSB40% were provided as potential overfishing definitions based on the precedence offered by GARM-III (NEFSC 2008), instead of other potential Percent Maximum Spawning Potential (%MSP) alternatives.

The Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish (NEFSC 2002) estimated biological reference points for SNE/MA winter flounder using Yield Per Recruit (YPR) and SSB per Recruit (SSBR) analyses (Thompson and Bell 1934) and Beverton-Holt stock-recruitment models (Beverton and Holt 1957, Brodziak et al. 2001, Mace and Doonan 1988) based on the SAW 28 assessment results (NEFSC 1999). A Beverton-Holt stock-recruitment model fit with a prior on unfished recruitment (R0) equal to the average of the five largest year classes (1981-1985) in the VPA time series was selected as the best stock-recruitment model. The YPR and SSBR analyses indicated that F0.1 = 0.25 and F40%= 0.21. The NEFSC (2002) stock-recruitment model indicated that MSY = 10,600 mt, FMSY= 0.32, and SSBMSY= 30,100 mt.

Both the parametric Beverton-Holt stock-recruitment model and the "non-parametric empirical" approach (YPR and SSBR model combined with VPA recruitment estimates and long-term projections) were considered in the 2008 GARM-III assessment to estimate biological reference points for SNE/MA winter flounder, based on the BASE and SPLIT VPA results. Stock-recruitment data were modeled for the 1981-2007 year classes (1981-2007 SSB; 1982-2008 recruitment at age 1). In the non-parametric empirical approach, a long-term (100 year) stochastic projection using the cumulative distribution function of the year classes produced when SSB exceeded 5,700 mt was used to estimate MSY and SSBMSY.

The 2008 GARM-III Biological Reference Point Review Panel (NEFSC 2008) concluded that the prior on unfished recruitment used to fit the parametric Beverton-Holt stock-recruitment model in the NEFSC (2002) work was inappropriate. The Beverton-Holt stock-recruitment model fit without the prior or with a prior on steepness (*h*) did not provide feasible results. The Panel therefore recommended the non-parametric empirical approach be used to estimate biological reference points for SNE/MA winter flounder based on a) the GARM-III SPLIT VPA results, b) the estimate of F40% as a proxy for FMSY, and c) a long-term (100 year) stochastic projection using the cumulative distribution function of the year classes produced when SSB exceeded 5,700 mt (1981-1988 year classes; mean R = 35.239 million fish at age 1) to estimate MSY and SSBMSY. The 2008 GARM-III BRPs were F40% = 0.248 (proxy for FMSY and the fishing mortality threshold for overfishing), SSB40% = 38,861 mt (proxy for SSBMSY), and MSY40% = 9,742 mt (proxy for MSY). The biomass threshold was therefore 19,381 mt (proxy threshold for overfished).

In the current assessment for SNE/MA winter flounder, FMSY, SSBMSY, and MSY BRPs were estimated from an external stock-recruitment model for both the final CAT10 model and the alternative STEPM model estimates with future M = 0.3 or future M = 0.6 (Figure A71). Stock-recruitment parameters using no prior, a prior on steepness (*h* = 0.8; CV = 0.09; as in NEFSC 2002, as derived from Myers et al. 1999), and a prior on unfished recruitment (R0; mean of the five largest estimated recruitments [1981-1985] as in NEFSC 2002) were estimated. Proxy BRPs based on 40% MSP were also estimated for the models. Table A43 summarizes the stock-recruitment model fit results, and Table A44 summarizes the YPR and SSBR calculation results. For the final CAT10 model, the stock-recruitment model with a prior for steepness (*h*) was judged to fit best while providing feasible results (Figures A72-A73); for the two STEPM models, the fits with no priors were judged to fit best while providing feasible results (Figures A74-A77). YPR and SSBR calculations were used with fishery selectivity estimates for all three model configurations to provide 40%MSP based proxy BRPs.

The SARC 52 review panel concluded that steepness should be similar between the three winter flounder stocks in Northeast U.S waters. Therefore, FMSY, SSBMSY, and MSY were estimated from a stock-recruitment model using a range of values for steepness (slope of the stock recruitment curve near the origin) which was consistent with the stock-recruitment data. In computing the BRPs, values of steepness were chosen which were constructed to be as similar as possible between stocks, while also providing good fits to the stock recruitment data for each stock. For the SNE/MA stock, steepness was therefore set at 0.61, based on the likelihood profile over a range of fixed steepness values. The final recommended biological reference points for SNE/MA winter flounder are FMSY = Fthreshold = 0.290, SSBMSY = Btarget = 43,661 mt, 1/2 SSBMSY = Bthreshold = 21,831 mt, and MSY = 11,728 mt. For comparison, F40% computed using the same biological and fishery characteristics is 0.327, with SSB40% = 29,045 mt and MSY40 = 8,903 mt (Figures A78-A80).

TOR 7. Evaluate stock status (overfished and overfishing) with respect to the "new" BRPs (from TOR 6), and with respect to the existing BRPs (from a previous accepted peer review) whose values have been updated.

Table A45 summarizes the existing 2008 GARM-III BRPs for SNE/MA winter flounder (NEFSC 2008) and the recommended BRPs from the current assessment. In the current assessment, the assumed value for M has been increased from 0.2 to 0.3, and so the SDWG concluded that comparison of current assessment F and SSB estimates with the existing 2008 GARM-III reference points was not appropriate. The summary stock status statements below are based on the three assessment models and associated BRP configurations.

ASAP CAT10 M = 0.3

The Southern New England/Mid-Atlantic (SNE/MA) winter flounder stock complex was overfished but overfishing was not occurring in 2010 (Table A45, Figures A81-A83). Fishing mortality (F age 4-5) in 2010 was estimated to be 0.051, below FMSY = 0.290 (18% of FMSY) and below F40% = 0.327 (16% of F40%).

SSB in 2010 was estimated to be 7,076 mt, about 16% of SSMSY= 43,661 mt and 24% of SSB40% = 29,045 mt.

The SDWG recommends the ASAP CAT10 M = 0.3 model with stock-recruitment model based MSY BRPs as the basis for current and future stock status. The SDWG acknowledged the persistent retrospective pattern in this model, but does not recommend any adjustment to the 2010 assessment estimates.

ASAP STEPM M = 0.3

The Southern New England/Mid-Atlantic (SNE/MA) winter flounder stock complex was overfished but overfishing was not occurring in 2010 (Table A45). Fishing mortality (F age 4-5) in 2010 was estimated to be 0.087, below FMSY = 0.325 (27% of FMSY) and below F40% = 0.327 (27% of F40%). SSB in 2010 was estimated to be 4,144 mt, about 10% of SSMSY= 42,770 mt and 13% of SSB40% = 31,311 mt.

The SDWG provides the STEPM M = 0.3 model and associated BRPs as an alternative that reduces the persistent retrospective pattern in the model, while projecting that M, as a proxy for the factors that cause the retrospective patterns, will return to the base value of 0.3 in the future. The SDWG acknowledges that some retrospective pattern remains in this model, but does not recommend any adjustment to the 2010 assessment estimates.

ASAP STEPM M = 0.6

The Southern New England/Mid-Atlantic (SNE/MA) winter flounder stock complex was not overfished and overfishing was not occurring in 2010 (Table A45). Fishing mortality (F age 4-5) in 2010 was estimated to be 0.087, below FMSY = 0.145 (60% of FMSY) and below F40% = 0.652 (13% of F40%). SSB in 2010 was estimated to be 4,144 mt, about 60% of SSMSY= 6,899 mt and 60% of SSB40% = 6,926 mt.

The SDWG provides the STEPM M = 0.6 model and associated BRPs as an alternative that reduces the persistent retrospective pattern in the model, while projecting that M, as a proxy for the factors that caused the retrospective patterns, will remain at an elevated value of 0.6 in the future. The SDWG notes that the ASAP STEPM M = 0.6 model configuration and associated BRPs with future M = 0.6 provides substantially different perceptions of stock productivity, or "state of nature," for SNE/MA winter flounder both historically and in 2010 and beyond if M = 0.6 is assumed in the future, compared to assessment models and BRPs with M = 0.3. The SDWG did not come to consensus on whether the STEPM M=0.6 configuration provides a feasible assessment of SNE/MA winter flounder stock status in 2010 or into the future.

TOR 8. Develop and apply analytical approaches and data that can be used for conducting single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs) under a set of alternative harvest scenarios. If the stock needs to be rebuilt, take that into account in these projections.

> **a. Provide numerical short-term projections (3-5 yrs, or through the end of the rebuilding period, as appropriate). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions about the most important uncertainties in the assessment (e.g., terminal year abundance, variability in recruitment).**
>
> **b. Take into consideration uncertainties in the assessment and the species biology to describe this stock's vulnerability (see "Appendix to the SAW TORs") to becoming or remaining overfished, and how this could affect the choice of ABC.**
>
> **c. Develop plausible hypotheses (e.g., mixing among the three stocks) which might explain any conflicting trends in the data and undertake scenario analyses to evaluate the consequences of these alternate hypotheses on ABC determination.**

8a. Projections of future stock status were made based on the current assessment results for both the CAT10 and STEPM models and corresponding BRPs. Mean weight, maturity and fishery selectivity patterns at age estimated for the most recent 5 years in the assessment (2006-2010) were used to reflect current conditions in the stock and fishery. Recruitment was projected using stock-recruitment models for the MSY-based BRPs, while two-stage recruitment models (resample the cumulative density function [cdf] of the lowest 23 year classes [1986-2010] for SSB less than 10,000 mt; resample the cdf of the highest 5 year classes [1981-1985] for SSB greater than 10,000 mt) were used for the 40%MSP based BRPs, to ensure that the magnitude of short-term recruitment would be appropriate for the magnitude of SSB. The projections assumed the FMP Framework 44 fishing year (May 1) catch of 842 mt would be landed as a calendar year (Jan 1) catch in 2011.

ASAP CAT10 M = 0.3

A catch of 842 mt in 2011 is projected to provide median F2011 = 0.100 and median SSB2011 = 9,177 mt. Projections at F = 0.000 in 2012-2014 indicate less than a 1% chance that the stock will rebuild to SSBMSY = 43,661 mt by 2014, and less than a 4% chance that the stock will rebuild to SSB40% = 29,045 mt by 2014.

ASAP STEPM M = 0.3

A catch of 842 mt in 2011 is projected to provide median F2011 = 0.174 and median SSB2011 = 4,720 mt. Projections at F = 0.000 in 2012-2014 indicate less than a 1% chance that the stock will rebuild to SSBMSY = 42,770 mt by 2014, and less than a 1% chance that the stock will rebuild to SSB40% = 31,311 mt by 2014.

ASAP STEPM M = 0.6

A catch of 842 mt in 2011 is projected to provide median F2011 = 0.202 and median SSB2011 = 4,429 mt. Projections at F = 0.000 in 2012-2014 indicate less than a 4% chance that the stock will rebuild to SSBMSY = 6,899 mt by 2014, and a 31% chance that the stock will rebuild to SSB40% = 6,926 mt by 2014.

8b. The Working Group accounted for vulnerability, productivity and susceptibility using conventional MSY reference points, and evaluated uncertainty using model estimates of precision and qualification of other uncertainties. Age-based analytical stock assessment models and associated MSY reference point evaluations provide a relatively comprehensive and synthetic evaluation of vulnerability that is consistent with stock status determination and projection. Vulnerability and susceptibility were accounted for in both aspects of status determination (estimation of F and FMSY) and projections as the magnitude of fishing mortality and recent fishery selectivity at age. All components of productivity (reproduction, individual growth, and survival) were also explicitly accounted for in stock status determination and projections. Reproduction was monitored as age-1 recruitment, and projected as a function of SSB (the product of abundance, weight and maturity at age). Individual growth was monitored as empirical size at age, and projected as recent mean size at age. Survival was accounted for based on model estimates of fishing mortality and selectivity as well as assumed natural mortality, which was informed by tagging analysis.

Uncertainties that were not accounted for by assessment and reference point models were evaluated using model diagnostics. Standard model diagnostics (e.g., residual analyses, retrospective analyses) were used for model validation. Retrospective inconsistencies that were outside the bounds of model precision estimates were addressed through selection of alternative models.

Vulnerabilities that were not accounted for by assessment and reference point models were evaluated using exploratory modeling, habitat observations and testing the influence of environmental factors on recruitment dynamics. All three winter flounder stocks are harvested in mixed-stock fisheries, but bycatch and discards are monitored and managed through Annual Catch Limits with Accountability Measures for exceeding those limits.

Additional considerations of vulnerability and productivity are the implications of shifts in distribution, recruitment dynamics and increased natural mortality. Nye et al. (2009) found an annual increase in mean depth (0.8 m per year) of the winter flounder distribution, which may have productivity and vulnerability implications. Apparent decreases in estuarine spawning or shifts toward coastal spawning (e.g., DeCelles and Cadrin 2010) may also have implications for vulnerability (e.g., less availability to recreational fisheries) and productivity (less larval retention). Consumption of winter flounder by other fishes, birds and mammals may be increasing as these predator populations increase.

A considerable source of additional vulnerability is the continued weak recruitment and low reproductive rate (e.g., recruits per spawners) of SNE/MA winter flounder (Figure A84). If weak recruitment and low reproductive rate continues, productivity and rebuilding of the stock will be less than projected. Stock-recruit modeling suggests that warm temperatures are having a negative effect on recruitment of SNE/MA winter flounder.

8c. The primary Research Recommendations from the 2008 GARM-III assessments for winter flounder were: "Assessment approaches needs [*sic*] to be explored that consider all three Winter Flounder stocks as a stock complex within which there is significant interaction amongst the individual stock components." and "The Panel also had concerns about the unit stock, not only for this stock, but for all of the Winter Flounder stocks assessed. It recommended an analysis of Winter Flounder as a stock complex, rather than as individual stocks, be undertaken" (NEFSC 2008).

As noted earlier, the stocks are defined as they are now based on a) historical tagging studies that show low rates of exchange (a few percent) between the stock areas (Howe and Coates 1975; Pereira *et al.* 1999), b) differences in the growth rates between the stocks, with GBK fish growing faster, GOM fish growing slower, and SNE fish growing at an intermediate rate (How and Coates 1975; Lux 1973; NEFSC 2008), c) differences in the rates of maturation (NEFSC 2008), d) differences in meristics, mainly fin ray counts (Lux *et al*. 1970), and e) fishery "integration" of catches from potential bay/estuarine specific-stocks in the GOM and the SNE "complexes."

Terceiro (MS 2011b) provided an exercise which responded to the GARM-III Research Recommendations aggregating all 3 stocks together in an “All Stocks” winter flounder ADAPT VPA (back-calculating model) - i.e., to assume 100% "interaction". Stock size and fishing mortality rate estimates from the combined analysis were a “blend” of the three GARM assessment results, as might be expected. Aggregation of the three stock units resulted in a larger aggregate spawning stock biomass reference point and MSY estimate, while the aggregate stock status remained overfished with overfishing occurring in 2007. The combined analysis exhibited a reduced retrospective pattern compared to those in the GARM-III GOM and SNE assessments (recent overestimation of SSB ranging from 8-15%; underestimation of F ranging up to 22%).

However, the SDWG notes that the exercise violated the existing assumptions of stock structure based on information about the biology, migration patterns, and fishing patterns for winter flounder. The SDWG concludes that the information available on winter flounder stock structure provides strong support for the current three stock units, and that attempts to model those units as a single complex are not worth pursuing further. The SDWG does not believe that the benefits from the single-stock analysis (a single analysis instead of three; reduced retrospective pattern; ability to model the Gulf of Maine unit within the complex) are sufficient to ignore the observed differences in biological traits (growth, maturity, fecundity) that affect the interpretation of the spawning stock reproductive potential of the three current units.

The SDWG has initiated further research pursuing use of a more complex model (i.e., Stock Synthesis) to maintain separate fishery and survey catch for the three current stock units, while allowing a small amount (a few percent) of exchange between the stock units based on information from historical tagging. However, development of that research has not progressed sufficiently to be made available for peer review at this time.

TOR 9. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

Previous from 2002 SAW 36:

1) Evaluate the maturity at age of fish sampled in the NEFSC fall and winter surveys.

Fall survey data have been evaluated; winter survey samples have not been processed

2) Consider fieldwork to record ovary weights along with maturity stage data from 20-30 cm fish in the NEFSC and State agency surveys for 1-2 years to help resolve age/size at maturity differences between State and NEFSC surveys.

See McBride et al MS 2011

3) Conduct periodic maturity staging workshops involving State and NEFSC trawl survey staff.
Not addressed, but recommended as new RR3

4) Examine sources of the differences between NEFSC, MA and CT survey maturity (validity of evidence for smaller size or younger age at 50% maturity in the NEFSC data). Compare NEFSC inshore against offshore strata for differences in maturity. Compare confidence intervals for maturity ogives. Calculate annual ogives and investigate for progression of maturity changes over time. Examine maturity data from NEFSC strata on Nantucket Shoals and near George=s Bank separately from more inshore areas. Consider methods for combining maturity data from different survey programs.

Significant work completed for this assessment, and see McBride et al MS 2011

5) Increase the intensity of commercial fishery discard length sampling.

Completed for 2008 GARM 3 - adopted SBRM algorithm and increased sample request

6) Consider post-stratification of NEFSC survey offshore stratum 23, to facilitate inclusion of survey catches from this stratum (east of Cape Cod) in the SNE-MA winter flounder assessment.

See GBK winter flounder assessment – stratum 23 used in GBK assessment based on characteristics of age samples

7) Incorporate State samples (e.g. NY DEC Party Boat Survey and CT DEP Volunteer Angler Survey) in the estimation of recreational fishery landings and discards, if possible.

Completed for 2008 GARM 3

8) Attempt use of a forward projection (statistical catch at age model) in the next assessment.

Completed for 2008 GARM 3; see TOR3 current assessment final model

9) Continue to consider the effects of catch-and-release components of recreational fishery on discard at age (i.e., develop mortality estimates from the American Littoral Society tagging database, if feasible).

Not addressed

10) Compare commercial fishery discard estimates from the Mayo survey/mesh algorithm with those from VTR data for comparable time periods.

Completed for 2008 GARM 3 - adopted SBRM algorithm; see TOR 1

11) Maintain or increase sampling levels (currently supported by individual state funding) and collect age information from MRFSS samples.

Not addressed

12) Examine the implications of anthropogenic mortalities caused by pollution and power plant entrainment in estimating yield per recruit, if feasible.

Not directly addressed - although the power plant on Mount Hope Bay in MA has built two large cooling towers in part to reduce larval fish mortality

13) Examine the implications of stock mixing from data from Great South Channel region.

See Terceiro MS 2011b

14) Expand sea sampling for estimation of commercial discards.

Completed for 2008 GARM 3 - adopted SBRM algorithm and increased sample request; see TOR 1

15) Revise the recreational fishery discard estimates by applying a consistent method across all years, if feasible (i.e., the Gibson 1996 method).

A consistent method has been applied following approaches adopted for Mid-Atlantic species (although not the Gibson 1996 method)

Previous from 2008 GARM-III:

1) Assessment approaches needs [*sic*] to be explored that consider all three Winter Flounder stocks as a stock complex within which there is significant interaction amongst the individual stock components. The Panel also had concerns about the unit stock, not only for this stock, but for all of the Winter Flounder stocks assessed. It recommended an analysis of Winter Flounder as a stock complex, rather than as individual stocks, be undertaken.

See Terceiro MS 2011a

New from 2011 SAW 52:

1) Update and investigate migration rates between stock and movement patterns. The most recent comprehensive tagging study was completed in the 1960s (Howe and Coates), and a new large scale effort is warranted. Further investigate localized structure/genetics within the stocks.

2) Investigate the feasibility of port samplers collecting otoliths from large and lemon sole instead of scales because of problems under-ageing larger fish.

3) Investigate use of periodic gonad histology studies as a check to make ensure maturity estimates are accurate, with particular attention to obtaining sufficient samples from the Georges Bank stock. Explore options to conduct periodic maturity staging workshops involving State and NEFSC trawl survey staff.

4) Investigate the skipped spawning percentage for each stock, and estimate interannual variation when sufficient data have been collected.

5) Investigate ways to improve compliance to help VTR reporting. Currently about 300 of the 1500 permitted

vessels consistently under-report the number of statistical area fished.

6) Encourage support for Industry Based Surveys, which can provide valuable information on stock abundance, distribution, and catchability in research surveys that is independent of and supplemental to NMFS efforts.

7) Explore use of a more complex Stock Synthesis model with small rates of migration between stocks.

8) Develop time series of winter flounder consumption by the major fish predators of winter flounder.

9) Conduct studies to better understand recruitment processes of winter flounder, particularly in the GOM and on GBK.

10) Revise the NEFSC assessment software to include the ability to model S-R functions including environmental factors with errors/probabilities.

11) Further explore the relationship between large scale environmental forcing (e.g., temperature, circulation, and climate) for effects on life history, reproduction, and recruitment in the Georges Bank stock.

12) Explore development of an index of winter flounder larval abundance based on MARMAP, GLOBEC, etc., time series.

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Table A1. Winter flounder commercial landings (metric tons) for the Southern New England/Mid-Atlantic stock complex area (U.S. statistical reporting areas 521, 526, 533-539, 611-639) as reported by NEFSC weighout, dealer, state bulletin and general canvas data. PSE is the Proportional Standard Error (in percent) due to allocation to statistical area using Vessel Trip Reports (VTR) for 1995 and later years.

Year	Metric tons
1964	7,474
1965	8,678
1966	11,977
1967	9,478
1968	7,070
1969	8,107
1970	8,603
1971	7,367
1972	5,190
1973	5,573
1974	4,259
1975	3,982
1976	3,265
1977	4,413
1978	6,327
1979	6,543
1980	10,627
1981	11,176
1982	9,438
1983	8,659
1984	8,882
1985	7,052
1986	4,929
1987	5,172
1988	4,312
1989	3,670
1990	4,232
1991	4,823
1992	3,816
1993	3,010
1994	2,128

Table A1 continued.

Year	Metric tons	PSE
1995	2,593	0.4
1996	2,783	0.5
1997	3,548	0.7
1998	3,138	0.7
1999	3,349	0.5
2000	3,704	0.4
2001	4,556	0.4
2002	3,084	0.6
2003	2,308	0.5
2004	1,636	1.2
2005	1,320	1.2
2006	1,720	0.5
2007	1,628	0.6
2008	1,113	0.8
2009	271	2.3
2010	174	4.5

Table A2. Percent of landings by Area-Allocation level (ALEVEL A,B,C,D, and unallocated) for SNE/MA winter flounder.

	1995	1996	1997	1998	1999	2000	2001	2002	2003
A	63.6%	64.5%	60.8%	63.8%	66.4%	71.1%	69.9%	64.0%	69.6%
B	21.1%	19.4%	23.6%	19.3%	21.9%	18.9%	19.8%	24.2%	15.5%
C	6.5%	8.1%	8.5%	9.4%	5.9%	3.9%	5.2%	7.4%	9.5%
D	0.2%	0.2%	0.1%	0.1%	0.1%	0.4%	0.7%	0.3%	0.6%
Unallocated	8.6%	7.8%	6.9%	7.4%	5.8%	5.7%	4.4%	4.1%	4.8%
Grand Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

	2004	2005	2006	2007	2008	2009	2010	Total
A	59.2%	62.4%	70.8%	71.0%	69.3%	57.2%	27.8%	66.1%
B	20.6%	14.9%	16.6%	19.8%	25.7%	16.4%	43.4%	20.4%
C	4.6%	9.4%	5.2%	5.5%	3.8%	21.6%	19.0%	6.8%
D	9.6%	8.6%	3.0%	0.3%	0.7%	2.4%	9.3%	1.2%
Unallocated	6.0%	4.7%	4.3%	3.5%	0.5%	2.3%	0.5%	5.5%
Grand Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table A3. Distribution of commercial landings (percentage of annual total) of winter flounder from the Southern New England/Mid-Atlantic stock complex area by U.S. statistical reporting area. 1989-1994 from NEFSC Port Agent interviews; 1995 and later from Vessel Trip reports (VTR).

	Area								
Year	521	526	537	538	539	611	612	613	614-622
1989	33.2	10.8	18.9	7.0	12.1	7.1	5.5	4.2	1.2
1990	39.4	14.7	17.3	4.3	8.2	9.7	3.6	1.7	1.2
1991	46.4	14.7	10.8	1.7	13.7	5.7	3.6	2.9	0.5
1992	37.0	12.6	17.4	2.4	9.4	10.1	4.5	3.4	3.3
1993	46.6	10.0	10.8	2.4	8.2	7.7	4.2	8.0	2.1
1994	39.2	10.6	12.1	3.6	9.0	9.7	6.8	4.6	4.3
1995	45.1	4.8	8.8	2.6	13.7	7.6	10.9	4.7	1.9
1996	47.6	10.6	12.8	2.2	11.3	8.8	2.6	3.2	0.9
1997	60.6	5.3	8.0	2.5	11.3	6.5	1.8	2.9	1.0
1998	52.4	7.8	8.7	1.9	14.2	8.5	2.1	3.8	0.6
1999	50.6	8.0	8.5	2.2	9.8	8.6	7.5	4.2	0.8
2000	47.0	4.7	10.1	2.2	13.2	8.4	7.9	5.6	0.9
2001	56.1	6.3	8.0	1.0	9.6	5.7	6.7	5.2	1.6
2002	54.2	9.2	7.3	1.9	10.7	6.7	4.5	5.2	0.4
2003	50.8	5.7	6.5	3.1	11.3	8.5	8.6	4.2	1.3
2004	39.2	3.0	13.1	3.1	14.6	9.4	8.6	3.7	5.3
2005	41.1	5.3	15.9	3.5	14.9	3.9	7.3	2.8	5.3
2006	33.1	3.7	12.2	2.0	21.0	4.0	13.8	7.1	3.1
2007	37.3	1.8	9.8	2.0	21.0	6.4	11.5	7.0	3.0
2008	48.2	1.0	7.7	1.4	18.4	7.3	8.6	4.1	3.2
2009	22.1	1.2	9.3	5.9	27.4	8.1	5.8	8.8	11.3
2010	58.0	5.6	5.5	4.2	12.4	4.7	0.3	2.2	7.2

Table A4. Estimated number (N; 000s) and weight (mt) of winter flounder landed and discarded in the recreational fishery, from the Southern New England/Mid-Atlantic stock complex. PSE is Proportional Standard Error in percent.

Year	Landed A+B1 (N; 000s)	Landed A+B1 (N; PSE)	Landed A+B1 (mt)	Landed A+B1 (mt;PSE)	Released B2 (N; 000s)	Released B2 (PSE)	15% Release Mortality (N; 000s)	15% Release Mortality (mt)
1981	8253	17	3154	18	3007	25	451	91
1982	8216	31	3493	36	2163	48	324	63
1983	8295	17	3485	17	2699	25	405	127
1984	12441	19	5510	20	4968	21	745	148
1985	13086	27	5075	27	4785	30	718	230
1986	7001	21	2949	20	2337	23	351	66
1987	6857	18	3169	18	2342	23	351	61
1988	7354	16	3510	17	2811	21	422	69
1989	3799	30	1792	24	2297	57	345	49
1990	2487	17	1063	18	1359	18	204	31
1991	2808	19	1184	19	1539	24	231	51
1992	809	16	387	16	550	23	83	15
1993	1879	35	813	30	1305	27	155	31
1994	1203	21	594	21	864	26	80	29
1995	1348	21	650	23	792	23	119	32
1996	1607	21	714	20	1049	29	157	30
1997	1220	24	627	25	701	29	105	31
1998	584	30	290	30	425	36	64	13
1999	658	24	320	25	412	27	62	14
2000	1401	24	870	25	727	35	109	32
2001	892	23	549	23	528	25	79	14
2002	408	32	223	33	299	34	45	12
2003	572	23	323	22	189	35	28	11
2004	344	23	214	23	98	37	15	8
2005	215	37	124	37	269	30	40	14
2006	273	38	136	40	318	34	48	16
2007	215	38	116	40	74	42	11	5
2008	76	29	73	30	42	36	6	3
2009	113	29	86	29	140	28	21	9
2010	56	39	28	51	95	40	14	8

Table A5. Estimated commercial fishery discard losses in metric tons and numbers (000s) for Southern New England/Mid-Atlantic winter flounder for 1981-1993 using the "mesh-selection" approach. Estimates assume a 50% discard mortality rate.

Year	Metric tons	Numbers (000s)
1981	1,343	5,123
1982	1,149	4,271
1983	1,311	5,251
1984	986	3,936
1985	1,534	4,531
1986	1,273	4,902
1987	950	3,545
1988	904	3,729
1989	1,404	5,761
1990	673	2,567
1991	784	2,700
1992	511	1,812
1993	457	1,580

Table A6. NEFSC Fishery Observer Program observed trips in the trawl and scallop dredge fisheries (in SNE/MA winter flounder stock areas) and precision (Proportional Standard Error; %) of discard estimates (metric tons). Estimates assume a 50% discard mortality rate

Year	Fishery	N Trips	Discards (Live mt)	Discards (Dead mt)	PSE (%)
1994	Trawl	111	650	325	35
	Scallop	56	32	16	31
1995	Trawl	248	261	131	33
	Scallop	65	57	29	16
1996	Trawl	216	138	59	50
	Scallop	86	212	106	15
1997	Trawl	159	105	53	32
	Scallop	63	449	225	16
1998	Trawl	98	230	115	41
	Scallop	45	116	58	15
1999	Trawl	123	38	19	43
	Scallop	26	86	43	20
2000	Trawl	186	137	59	31
	Scallop	140	159	80	27
2001	Trawl	244	39	20	35
	Scallop	161	17	9	16
2002	Trawl	248	108	54	23
	Scallop	187	78	39	51
2003	Trawl	383	69	35	27
	Scallop	138	201	101	31
2004	Trawl	854	137	69	20
	Scallop	458	31	16	36
2005	Trawl	1220	127	64	27
	Scallop	406	83	42	27
2006	Trawl	612	199	100	21
	Scallop	257	103	52	17
2007	Trawl	902	151	76	18
	Scallop	457	77	39	16
2008	Trawl	650	113	57	25
	Scallop	624	104	52	21
2009	Trawl	849	270	135	35
	Scallop	383	60	30	35
2010	Trawl	1153	193	97	31
	Scallop	331	112	56	38

Table A7. Total number of fish lengths sampled from the commercial fishery by market category for Southern New England/Mid-Atlantic winter flounder. The landings (metric tons) and metric tons per 100 lengths are also shown.

	Market Category						
Year	Unclass	Large	Medium	Small	Total	Landings (mt)	Metric tons per 100 lengths
1981	1,904	918	0	1,638	4,460	11,176	251
1982	784	2,932	978	3,348	8,042	9,438	117
1983	927	2,044	1,044	1,921	5,936	8,659	146
1984	551	1,338	637	1,439	3,965	8,882	224
1985	716	1,396	1,663	2,632	6,407	7,052	110
1986	799	1,091	1,024	2,206	5,120	4,929	96
1987	99	1,978	670	2,524	5,271	5,172	98
1988	269	1,250	958	1,731	4,208	4,312	102
1989	106	975	1,220	1,224	3,525	3,670	104
1990	102	1,333	1,180	1,473	4,088	4,232	104
1991	0	917	921	1,220	3,058	4,823	158
1992	402	1,159	1,259	1,343	4,163	3,816	92
1993	62	642	401	1,249	2,354	3,010	128
1994	327	600	644	912	2,483	2,128	86
1995	589	758	225	1,295	2,867	2,593	90
1996	580	764	324	1,027	2,695	2,783	103
1997	201	1,140	1,097	1,614	4,052	3,548	88
1998	942	415	1,325	734	3,416	3,138	92
1999	2,381	700	607	682	4,370	3,349	77
2000	1,553	1,075	942	2,580	6,150	3,704	60
2001	658	2,384	2,222	1,129	6,393	4,556	71
2002	716	1,608	1,099	1,983	5,406	3,084	57
2003	1,037	1,626	692	1,115	4,470	2,308	52
2004	373	1,974	652	1,822	4,821	1,636	34
2005	239	2,283	721	627	4,294	1,320	31
2006	1,614	2,661	1,805	1,408	7,488	1,720	23
2007	2,974	4,026	1,661	1,344	10,005	1,628	16
2008	1,268	3,541	1,298	1,323	7,430	1,113	15
2009	105	1,750	748	159	2,762	271	10
2010	230	166	0	50	446	174	39

Table A8. Winter flounder commercial fishery landed lengths (number of fish measured) sampled from the Southern New England/Mid-Atlantic stock complex; landings are in metric tons.

1998 Market Category

Sample Type	Season	Unclass.	Small	Medium	Large	Total
Port	Jan-Jun	162	105	767	205	1239
Port	Jul-Dec	780	794	558	210	2342
Total lengths used		942	899	1325	415	3581
Landings		644	1453	438	673	3208
Metric tons per 100 lengths		68	162	33	162	90

1999 Market Category

Sample Type	Season	Unclass.	Small	Medium	Large	Total
Port	Jan-Jun	978	334	502	522	2336
Port	Jul-Dec	1403	464	105	299	2271
Total lengths used		2381	798	607	821	4607
Landings		838	1566	290	750	3444
Metric tons per 100 lengths		35	196	48	91	75

2000 Market Category

Sample Type	Season	Unclass.	Small	Medium	Large	Total
Port	Jan-Jun	808	377	1868	126	3179
Port	Jul-Dec	845	565	1025	839	3274
Total lengths used		1653	942	2893	965	6453
Landings		848	451	1670	815	3784
Metric tons per 100 lengths		51	48	58	84	59

Table A8 continued.

2001 Market Category

Sample Type	Season	Unclass.	Small	Medium	Large	Total
Port	Jan-Jun	557	510	969	628	2664
Port	Jul-Dec	101	387	1234	1656	3378
Total lengths used		658	897	2203	2284	6042
Landings		882	1211	1571	1023	4687
Metric tons per 100 lengths		134	135	71	45	78

2002 Market Category

Sample Type	Season	Unclass.	Small	Medium	Large	Total
Port	Jan-Jun	482	278	633	843	2236
Port	Jul-Dec	206	2254	466	738	3664
Total lengths used		688	2532	1099	1581	5900
Landings		513	775	936	912	3136
Metric tons per 100 lengths		75	31	85	58	53

2003 Market Category

Sample Type	Season	Unclass.	Small	Medium	Large	Total
Port	Jan-Jun	642	124	315	947	2028
Port	Jul-Dec	259	1112	566	713	2650
Total lengths used		901	1236	881	1660	4678
Landings		559	856	242	770	2427
Metric tons per 100 lengths		62	69	27	46	52

Table A8 continued.

2004 Market Category						
Sample Type	Season	Unclass.	Small	Medium	Large	Total
Port	Jan-Jun	150	474	305	1092	2021
Port	Jul-Dec	223	1348	347	882	2800
Total lengths used		373	1822	652	1974	4821
Landings		390	428	174	644	1636
Metric tons per 100 lengths		105	23	27	33	34

2005 Market Category						
Sample Type	Season	Unclass.	Small	Medium	Large	Total
Port	Jan-Jun	239	287	270	787	1583
Port	Jul-Dec	424	340	451	1496	2711
Total lengths used		663	627	721	2283	4294
Landings		205	423	131	561	1320
Metric tons per 100 lengths		31	67	18	25	31

2006 Market Category						
Sample Type	Season	Unclass.	Small	Medium	Large	Total
Port	Jan-Jun	613	188	1073	1349	3223
Port	Jul-Dec	1001	1220	732	1312	4265
Total lengths used		1614	1408	1805	2661	7488
Landings		273	551	286	610	1720
Metric tons per 100 lengths		17	39	16	23	23

Table A8 continued.

2007 Market Category

Sample Type	Season	Unclass.	Small	Medium	Large	Total
Port	Jan-Jun	811	68	635	702	2216
Port	Jul-Dec	2163	1276	1026	3324	7789
Total lengths used		2974	1344	1661	4026	10005
Landings		295	451	290	591	1627
Metric tons per 100 lengths		10	34	17	15	16

2008 Market Category

Sample Type	Season	Unclass.	Small	Medium	Large	Total
Port	Jan-Jun	1012	280	701	1714	3707
Port	Jul-Dec	256	1043	597	1827	3723
Total lengths used		1268	1323	1298	3541	7430
Landings		128	499	162	324	1113
Metric tons per 100 lengths		10	38	12	9	15

2009 Market Category

Sample Type	Season	Unclass.	Small	Medium	Large	Total
Port	Jan-Jun	105	159	594	1306	2164
Port	Jul-Dec	0	0	154	444	598
Total lengths used		105	159	748	1750	2762
Landings		27	61	70	113	271
Metric tons per 100 lengths		26	38	9	6	10

Table A8 continued.

2010 Market Category						
Sample Type	Season	Unclass.	Small	Medium	Large	Total
Port	Jan-Jun	128	0	0	58	186
Port	Jul-Dec	102	50	0	108	260
Total lengths used		230	50	0	166	466
Landings		9	66	36	63	174
Metric tons per 100 lengths		4	132	0	38	37

Table A9. Total number of fish lengths sampled from the recreational fishery for Southern New England/Mid-Atlantic winter flounder. The landings (metric tons) and metric tons per 100 lengths are also shown.

Year	Landings	Lengths	Metric tons per 100 lengths
1981	3,154	1,725	183
1982	3,493	1,971	177
1983	3,485	2,587	135
1984	5,510	3,123	176
1985	5,075	2,357	215
1986	2,949	2,237	132
1987	3,169	1,360	233
1988	3,510	1,944	181
1989	1,792	2,810	64
1990	1,063	2,548	42
1991	1,184	1,755	67
1992	387	1,083	36
1993	813	1,288	63
1994	594	948	63
1995	650	767	85
1996	714	936	76
1997	627	752	83
1998	290	1030	28
1999	320	643	50
2000	870	360	242
2001	549	922	60
2002	223	657	34
2003	323	355	91
2004	214	449	48
2005	124	134	93
2006	136	101	135
2007	116	43	270
2008	73	85	86
2009	86	14	614
2010	28	49	57

Table A10. The total number of lengths sampled from the commercial fishery discards for Southern New England/Mid-Atlantic winter flounder. The discard quantity is before the 50% mortality rate is applied (metric tons); sampling intensity expressed as metric tons per 100 lengths sampled.

Year	Live Discards	Lengths	Metric tons per 100 lengths
1994	682	307	222
1995	318	719	44
1996	350	603	58
1997	554	968	57
1998	346	774	45
1999	124	367	34
2000	296	481	62
2001	56	307	18
2002	186	942	20
2003	370	1,185	31
2004	168	2,889	6
2005	210	3,318	6
2006	302	3,942	8
2007	236	4,093	6
2008	218	1,556	14
2009	330	4,888	7
2010	305	5,524	6

Table A11. Commercial fishery landings at age for the Southern New England/Mid-Atlantic winter flounder stock complex.

Commercial Landings at Age

	Age														
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	Total	7+
1981	194	7,154	9,740	2,750	606	178	42	32	0	0	9	0	0	20,705	83
1982	54	6,897	8,496	2,715	488	187	78	59	21	17	7	7	0	19,026	189
1983	6	2,795	7,114	3,957	1,322	584	269	91	34	70	6	29	35	16,312	534
1984	0	4,518	6,367	3,197	1,503	768	355	158	67	86	27	33	37	17,116	763
1985	27	3,936	5,688	3,052	1,014	326	104	32	17	7	5	2	0	14,210	167
1986	0	2,122	4,187	2,206	551	271	84	27	6	3	1	2	0	9,460	123
1987	0	2,488	5,465	1,895	465	122	40	20	14	12	2	0	0	10,523	88
1988	0	2,241	3,929	1,607	412	122	37	24	3	2	1	0	0	8,378	67
1989	0	1,542	4,057	1,747	431	58	34	13	5	1	0	0	0	7,888	53
1990	0	1,003	3,977	1,757	315	95	37	16	0	3	0	0	0	7,203	56
1991	0	1,406	4,756	2,239	447	143	48	16	5	1	1	0	0	9,062	71
1992	0	484	3,416	2,127	574	111	32	11	3	0	0	0	0	6,758	46
1993	13	885	2,516	1,377	361	102	71	7	0	0	2	0	1	5,335	81
1994	2	1,281	1,681	995	261	59	21	3	1	1	0	0	0	4,305	26
1995	0	116	2,067	1,935	424	77	13	6	1	0	0	0	0	4,639	20
1996	108	564	2,283	1,676	445	119	22	18	0	0	0	0	0	5,235	40
1997	1	1,485	2,705	1,734	387	60	23	12	3	1	0	0	0	6,411	39
1998	0	975	2,691	1,515	492	178	63	3	7	0	0	0	0	5,924	73
1999	0	1,962	3,658	1,380	311	59	12	4	0	0	0	0	0	7,386	16
2000	0	1,066	2,804	1,934	518	91	42	10	0	0	0	0	0	6,465	52
2001	0	1,524	3,186	1,963	717	169	65	30	10	2	1	0	0	7,667	108
2002	0	292	1,693	1,688	839	293	75	23	4	1	0	0	0	4,908	103
2003	0	342	1,469	1,068	432	152	56	31	4	0	0	0	0	3,554	91
2004	0	240	861	699	280	194	94	32	17	3	0	0	0	2,420	146
2005	0	239	648	667	286	108	35	22	6	3	0	0	0	2,014	66
2006	1	555	1,339	590	232	119	66	26	7	1	0	0	0	2,936	100
2007	0	297	1,286	825	256	65	24	4	1	1	0	0	0	2,759	30
2008	0	153	626	657	241	112	38	17	4	0	0	0	0	1,848	59
2009	0	5	167	197	158	43	8	3	1	0	0	0	0	582	12
2010	0	2	43	95	34	38	17	3	2	0	0	0	0	234	22

Table A12. Recreational fishery landings at age for the Southern New England/Mid-Atlantic winter flounder stock complex.

Recreational Landings at Age

	Age														
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	Total	7+
1981	792	4,136	2,475	757	60	4	28	0	0	0	0	0	0	8,253	28
1982	447	4,146	2,659	806	120	25	13	0	0	0	0	0	0	8,216	13
1983	287	1,616	4,159	1,687	424	111	10	0	0	0	0	0	0	8,295	10
1984	286	4,153	6,071	1,527	261	104	40	0	0	0	0	0	0	12,441	40
1985	216	1,560	4,202	2,517	1,865	1,489	864	0	330	43	0	0	0	13,086	1,237
1986	106	1,766	2,434	1,798	492	171	81	77	51	8	17	0	0	7,001	234
1987	16	920	1,725	1,016	2,215	629	81	114	64	77	0	0	0	6,857	336
1988	21	534	2,856	2,077	774	856	128	51	37	20	0	0	0	7,354	236
1989	102	762	974	1,238	397	166	94	37	17	8	3	1	0	3,799	160
1990	7	189	814	852	439	101	52	20	3	3	0	2	5	2,487	85
1991	13	233	1,128	883	401	108	38	0	1	0	3	0	0	2,808	42
1992	3	124	236	304	85	50	7	0	0	0	0	0	0	809	7
1993	49	370	511	459	347	86	32	16	6	3	0	0	0	1,879	57
1994	10	411	424	233	73	38	13	0	0	0	0	0	0	1,203	13
1995	2	243	779	238	80	6	0	0	0	0	0	0	0	1,348	0
1996	6	306	771	423	90	9	0	0	0	0	0	0	0	1,607	0
1997	1	83	504	416	181	36	0	0	0	0	0	0	0	1,220	0
1998	2	89	191	235	58	7	1	0	0	0	0	0	0	584	1
1999	1	101	340	151	49	16	0	0	0	0	0	0	0	658	0
2000	0	117	458	491	272	46	15	0	0	0	0	0	0	1,401	15
2001	1	83	265	299	165	62	16	0	0	0	0	0	0	892	16
2002	1	85	136	103	59	19	5	0	0	0	0	0	0	408	5
2003	1	100	257	103	51	36	25	0	0	0	0	0	0	572	25
2004	2	57	92	120	37	21	14	0	0	0	0	0	0	344	14
2005	0	54	67	55	22	11	6	0	0	0	0	0	0	215	6
2006	0	51	138	57	23	3	1	0	0	0	0	0	0	273	1
2007	0	1	82	100	16	10	8	0	0	0	0	0	0	215	8
2008	0	5	22	28	14	7	0	0	0	0	0	0	0	76	0
2009	0	19	30	24	19	12	9	0	0	0	0	0	0	113	9
2010	0	1	21	17	13	2	3	0	0	0	0	0	0	56	3

Table A13. Commercial fishery discards at age for the Southern New England/Mid-Atlantic winter flounder stock complex.

Commercial Discards at Age

	Age														
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	Total	7+
1981	322	2,514	2,186	101	0	0	0	0	0	0	0	0	0	5,123	0
1982	43	2,817	1,219	192	0	0	0	0	0	0	0	0	0	4,271	0
1983	260	2,479	2,000	467	45	0	0	0	0	0	0	0	0	5,251	0
1984	159	2,102	1,502	166	6	1	0	0	0	0	0	0	0	3,936	0
1985	22	1,504	2,516	442	43	4	0	0	0	0	0	0	0	4,531	0
1986	78	2,220	2,389	205	10	0	0	0	0	0	0	0	0	4,902	0
1987	11	1,600	1,755	170	9	0	0	0	0	0	0	0	0	3,545	0
1988	6	887	2,540	276	20	0	0	0	0	0	0	0	0	3,729	0
1989	315	2,724	2,131	555	33	2	1	0	0	0	0	0	0	5,761	1
1990	16	781	1,433	322	14	0	1	0	0	0	0	0	0	2,567	1
1991	17	1,238	1,205	227	12	1	0	0	0	0	0	0	0	2,700	0
1992	15	845	787	150	14	1	0	0	0	0	0	0	0	1,812	0
1993	201	849	467	57	6	0	0	0	0	0	0	0	0	1,580	0
1994	233	914	186	28	1	0	0	0	0	0	0	0	0	1,362	0
1995	86	254	193	25	3	0	0	0	0	0	0	0	0	561	0
1996	16	117	181	82	21	1	0	0	0	0	0	0	0	418	0
1997	73	205	256	102	16	0	0	0	0	0	0	0	0	651	0
1998	10	257	153	37	5	0	0	0	0	0	0	0	0	462	0
1999	2	30	57	45	16	7	2	0	0	0	0	0	0	158	2
2000	42	113	111	41	32	9	5	0	0	0	0	0	0	354	5
2001	12	44	35	11	1	0	0	0	0	0	0	0	0	102	0
2002	10	74	58	36	25	11	6	0	0	0	0	0	0	221	6
2003	8	47	68	26	16	35	19	0	0	0	0	0	0	219	19
2004	31	76	45	37	12	7	5	0	0	0	0	0	0	214	5
2005	22	107	47	30	17	12	8	0	0	0	0	0	0	243	8
2006	36	131	102	37	21	9	6	0	0	0	0	0	0	342	6
2007	7	37	87	81	17	10	5	0	0	0	0	0	0	243	5
2008	34	82	50	39	22	7	7	0	0	0	0	0	0	240	7
2009	82	164	68	45	31	10	8	0	0	0	0	0	0	408	8
2010	67	82	81	45	38	10	9	0	0	0	0	0	0	332	9

Table A14. Recreational fishery discards at age for the Southern New England/Mid-Atlantic winter flounder stock complex.

Recreational Discards at Age

	Age														
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	Total	7+
1981	72	379	0	0	0	0	0	0	0	0	0	0	0	451	0
1982	31	293	0	0	0	0	0	0	0	0	0	0	0	324	0
1983	63	342	0	0	0	0	0	0	0	0	0	0	0	405	0
1984	48	697	0	0	0	0	0	0	0	0	0	0	0	745	0
1985	9	342	365	2	0	0	0	0	0	0	0	0	0	718	0
1986	32	219	91	9	0	0	0	0	0	0	0	0	0	351	0
1987	47	257	43	3	1	0	0	0	0	0	0	0	0	351	0
1988	58	284	76	3	0	0	0	0	0	0	0	0	0	421	0
1989	51	247	46	1	0	0	0	0	0	0	0	0	0	345	0
1990	13	137	52	2	0	0	0	0	0	0	0	0	0	204	0
1991	22	152	57	0	0	0	0	0	0	0	0	0	0	231	0
1992	7	54	21	1	0	0	0	0	0	0	0	0	0	83	0
1993	29	96	26	4	0	0	0	0	0	0	0	0	0	155	0
1994	6	48	24	2	0	0	0	0	0	0	0	0	0	80	0
1995	1	41	73	4	0	0	0	0	0	0	0	0	0	119	0
1996	41	62	54	0	0	0	0	0	0	0	0	0	0	157	0
1997	14	68	23	0	0	0	0	0	0	0	0	0	0	105	0
1998	5	49	8	1	0	0	0	0	0	0	0	0	0	64	0
1999	2	53	6	1	0	0	0	0	0	0	0	0	0	62	0
2000	0	40	62	7	0	0	0	0	0	0	0	0	0	109	0
2001	22	39	17	1	0	0	0	0	0	0	0	0	0	79	0
2002	3	28	9	3	2	0	1	0	0	0	0	0	0	45	1
2003	6	9	7	2	2	0	1	0	0	0	0	0	0	28	1
2004	2	5	1	2	1	2	1	0	0	0	0	0	0	15	1
2005	10	17	3	4	3	3	0	0	0	0	0	0	0	40	0
2006	2	21	19	2	1	1	1	0	0	0	0	0	0	48	1
2007	0	1	5	5	1	0	0	0	0	0	0	0	0	11	0
2008	0	2	1	1	1	0	0	0	0	0	0	0	0	6	0
2009	1	8	6	2	3	1	0	0	0	0	0	0	0	21	0
2010	0	3	5	1	2	2	1	0	0	0	0	0	0	14	1

Table A15. Total fishery catch at age for the Southern New England/Mid-Atlantic winter flounder stock complex.

Total Catch at Age

	Age													
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	Total	7+
1981	1380	14183	14401	3608	666	182	70	32	0	0	9	0	0	34532	111
1982	575	14153	12374	3713	608	212	91	59	21	17	7	7	0	31837	202
1983	616	7232	13273	6111	1791	695	279	91	34	70	6	29	35	30263	544
1984	493	11470	13940	4890	1770	873	395	158	67	86	27	33	37	34238	803
1985	274	7342	12771	6013	2922	1819	968	32	347	50	5	2	0	32545	1404
1986	216	6327	9101	4218	1053	442	165	104	57	11	18	2	0	21714	357
1987	74	5265	8988	3084	2690	751	121	134	78	89	2	0	0	21276	424
1988	85	3946	9401	3963	1206	978	165	75	40	22	1	0	0	19882	303
1989	468	5275	7208	3541	861	226	129	50	22	9	3	1	0	17793	214
1990	36	2110	6276	2933	768	196	90	36	3	6	0	2	5	12461	142
1991	52	3029	7146	3349	860	252	86	16	6	1	4	0	0	14801	113
1992	25	1507	4460	2582	673	162	39	11	3	0	0	0	0	9462	53
1993	292	2200	3520	1897	714	188	103	23	6	3	2	0	1	8949	138
1994	251	2612	2339	1280	337	97	34	3	1	1	0	0	0	6956	39
1995	88	654	3112	2202	506	83	13	6	1	0	0	0	0	6667	20
1996	171	1050	3289	2181	556	129	22	18	0	0	0	0	0	7417	40
1997	88	1841	3488	2252	584	96	23	12	3	1	0	0	0	8388	39
1998	16	1371	3043	1788	555	185	64	3	7	0	0	0	0	7033	74
1999	5	2146	4062	1577	375	82	14	4	0	0	0	0	0	8265	18
2000	43	1336	3436	2473	822	146	62	10	0	0	0	0	0	8328	72
2001	35	1689	3503	2274	883	231	81	30	10	2	1	0	0	8740	124
2002	14	478	1897	1830	925	324	87	23	4	1	0	0	0	5583	115
2003	15	498	1802	1199	501	223	101	31	4	0	0	0	0	4374	136
2004	36	378	999	858	331	223	115	32	17	3	0	0	0	2992	167
2005	32	417	765	755	328	134	50	22	6	3	0	0	0	2512	81
2006	39	758	1598	686	277	133	74	26	7	1	0	0	0	3598	108
2007	7	335	1460	1010	290	84	36	4	1	1	0	0	0	3229	42
2008	34	243	699	725	278	126	45	17	4	0	0	0	0	2170	66
2009	83	195	271	268	211	66	26	3	1	0	0	0	0	1124	30
2010	67	87	150	159	87	52	30	3	2	0	0	0	0	637	35

Table A16. Total fishery catch mean weight at age for the Southern New England/Mid-Atlantic winter flounder stock complex.

Total Catch Mean Weights at Age

	Age						
Year	1	2	3	4	5	6	7+
1981	0.129	0.274	0.477	0.798	1.063	1.242	1.196
1982	0.092	0.263	0.440	0.697	1.052	1.257	1.840
1983	0.197	0.237	0.354	0.517	0.768	1.047	1.552
1984	0.148	0.261	0.370	0.546	0.695	0.915	1.284
1985	0.111	0.282	0.364	0.482	0.522	0.467	0.613
1986	0.129	0.292	0.398	0.480	0.685	0.879	0.961
1987	0.046	0.287	0.384	0.551	0.475	0.564	0.853
1988	0.039	0.279	0.351	0.508	0.634	0.517	0.827
1989	0.118	0.258	0.378	0.508	0.660	0.716	1.073
1990	0.082	0.295	0.394	0.525	0.672	0.808	0.990
1991	0.093	0.317	0.420	0.534	0.603	0.823	1.168
1992	0.079	0.287	0.427	0.599	0.802	0.945	1.395
1993	0.169	0.334	0.460	0.592	0.689	0.878	1.167
1994	0.311	0.430	0.473	0.564	0.750	0.985	1.281
1995	0.267	0.420	0.470	0.559	0.789	1.089	1.741
1996	0.136	0.380	0.464	0.607	0.824	0.851	1.085
1997	0.245	0.443	0.515	0.644	0.771	0.957	1.477
1998	0.196	0.362	0.465	0.568	0.665	1.090	1.116
1999	0.136	0.359	0.439	0.524	0.684	0.903	1.147
2000	0.106	0.407	0.492	0.622	0.729	0.975	1.079
2001	0.089	0.436	0.519	0.640	0.783	1.051	1.234
2002	0.135	0.372	0.499	0.617	0.747	0.927	1.143
2003	0.167	0.426	0.517	0.672	0.854	1.000	1.135
2004	0.094	0.384	0.549	0.619	0.786	0.945	1.251
2005	0.129	0.342	0.488	0.675	0.834	1.013	1.318
2006	0.118	0.379	0.468	0.652	0.872	1.065	1.289
2007	0.065	0.388	0.472	0.631	0.856	1.107	1.641
2008	0.110	0.355	0.479	0.598	0.755	0.937	1.275
2009	0.126	0.326	0.434	0.594	0.757	1.006	0.941
2010	0.127	0.329	0.505	0.615	0.766	0.899	1.075

Table A17. Total winter flounder recreational and commercial catch for the Southern New England/Mid-Atlantic stock complex in weight (metric tons; mt) and numbers (000s).

Year	Commercial Landings		Commercial Discards		Recreational Landings		Recreational Discards		Total Catch	
	mt	000s	mt	000s	mt	000s	mt	000s	Mt	000s
1981	11,176	20,705	1,343	5,123	3,154	8,253	91	451	15,764	34,532
1982	9,438	19,026	1,149	4,271	3,493	8,216	63	324	14,143	31,837
1983	8,659	16,312	1,311	5,251	3,485	8,295	127	405	13,582	30,263
1984	8,882	17,116	986	3,936	5,510	12,441	148	745	15,526	34,238
1985	7,052	14,210	1,534	4,531	5,075	13,086	230	718	13,891	32,545
1986	4,929	9,460	1,273	4,902	2,949	7,001	66	351	9,217	21,714
1987	5,172	10,523	950	3,545	3,169	6,857	61	351	9,352	21,276
1988	4,312	8,378	904	3,729	3,510	7,354	69	422	8,795	19,882
1989	3,670	7,888	1,404	5,761	1,792	3,799	49	345	6,915	17,793
1990	4,232	7,203	673	2,567	1,063	2,487	31	204	5,999	12,461
1991	4,823	9,062	784	2,700	1,184	2,808	51	231	6,842	14,801
1992	3,816	6,758	511	1,812	387	809	15	83	4,729	9,462
1993	3,010	5,335	457	1,580	813	1,879	31	155	4,311	8,949
1994	2,128	4,305	341	1,362	594	1,203	29	80	3,092	6,956
1995	2,593	4,639	159	561	650	1,348	32	119	3,434	6,667
1996	2,783	5,235	175	418	714	1,607	30	157	3,702	7,417
1997	3,548	6,411	277	651	627	1,220	31	105	4,483	8,388
1998	3,138	5,924	173	462	290	584	13	64	3,614	7,033
1999	3,349	7,386	62	158	320	658	14	62	3,745	8,265
2000	3,704	6,465	148	354	870	1,401	32	109	4,754	8,328
2001	4,556	7,667	28	102	549	892	14	79	5,147	8,740
2002	3,084	4,908	93	221	223	408	12	45	3,412	5,583
2003	2,308	3,554	185	219	323	572	11	28	2,827	4,374
2004	1,636	2,420	84	214	214	344	8	15	1,942	2,992
2005	1,320	2,014	105	243	124	215	14	40	1,563	2,512
2006	1,720	2,936	151	342	136	273	16	48	2,023	3,601
2007	1,627	2,760	118	243	116	215	5	11	1,866	3,229
2008	1,113	1,849	109	240	73	76	3	6	1,298	2,171
2009	271	452	165	408	87	113	9	21	532	994
2010	174	234	153	332	28	56	8	14	363	637

Table A18. NEFSC trawl survey index stratified mean number and mean weight (kg) per tow for the SNE/MA winter flounder stock complex. Spring and fall strata set (offshore 1-2, 5-6, 9-10, 25, 69-70, 73-74; inshore 2,5,8,11,14,17,20,23,26,29,45,46,56); winter strata set (offshore 1-2, 5-6, 9-10, 69, 73). Indices include door, gear, and vessel calibration factors.

	Spring					Fall			
Year	Number	N(CV)	Weight	W(CV)		Number	N(CV)	Weight	W(CV)
1976	1.512	19.6	0.441	19.9		2.827	32.3	1.491	43.0
1977	1.816	22.7	0.600	23.4		5.534	22.9	2.046	25.4
1978	3.290	13.1	0.950	15.6		4.451	17.7	1.701	22.6
1979	1.358	17.3	0.527	28.6		10.639	19.9	2.597	14.2
1980	8.284	19.3	2.073	15.1		10.176	33.9	3.552	32.0
1981	9.482	24.0	2.682	19.3		11.057	22.0	3.297	22.3
1982	5.407	28.7	1.366	23.5		4.959	20.0	1.605	21.1
1983	4.940	24.1	1.953	38.0		10.031	39.3	3.034	33.3
1984	4.173	13.8	1.384	13.4		2.748	23.1	0.883	23.6
1985	4.830	22.1	1.629	21.2		2.537	21.8	0.877	20.5
1986	2.147	30.2	0.741	28.7		1.597	25.0	0.460	23.2
1987	1.651	26.9	0.515	23.0		1.365	29.5	0.492	38.5
1988	2.034	22.5	0.705	21.8		1.172	19.4	0.461	22.9
1989	2.113	40.8	0.511	35.8		1.613	43.4	0.378	32.8
1990	2.147	41.1	0.510	36.6		2.267	30.8	0.608	27.6
1991	2.339	16.9	0.651	16.2		2.149	25.6	0.778	27.5

Table A18 continued.

	Spring				Fall				Winter			
Year	Number	N(CV)	Weight	W(CV)	Number	N(CV)	Weight	W(CV)	Number	N(CV)	Weight	W(CV)
1992	1.499	29.7	0.422	27.3	3.320	34.8	0.931	34.0	3.680	27.3	0.928	26.0
1993	0.925	23.6	0.199	18.3	1.321	29.3	0.383	28.9	2.590	29.4	0.456	21.5
1994	1.606	29.9	0.340	25.4	4.763	25.6	1.711	28.3	3.797	30.8	1.183	35.5
1995	2.111	27.8	0.588	22.7	2.133	21.9	0.649	18.6	2.221	26.1	0.697	29.1
1996	1.603	15.5	0.443	16.7	3.489	43.7	1.187	48.9	3.778	28.4	0.734	25.2
1997	1.489	25.5	0.413	23.0	9.136	33.8	3.024	27.5	3.906	19.7	1.043	21.6
1998	2.644	24.6	0.769	26.2	7.299	13.4	2.530	9.8	7.169	21.6	1.830	24.1
1999	4.292	18.9	1.228	19.9	4.137	17.4	1.825	16.8	10.328	31.8	3.100	32.3
2000	3.326	30.5	1.169	36.8	6.527	27.7	2.257	28.5	5.571	32.9	1.525	29.5
2001	1.690	15.8	0.598	15.0	3.387	29.5	1.324	33.0	3.096	31.6	0.873	29.0
2002	1.805	20.5	0.693	21.0	10.438	19.4	4.302	20.1	2.901	27.7	1.188	38.3
2003	0.746	14.1	0.256	13.5	3.527	24.9	1.704	28.6	2.199	42.1	0.782	42.0
2004	1.180	33.6	0.416	38.7	3.812	29.3	1.029	27.9	4.336	35.2	0.881	44.4
2005	1.019	31.7	0.335	33.0	4.379	30.0	1.574	32.8	4.045	30.4	1.143	26.0
2006	1.917	22.8	0.470	19.8	3.264	30.6	1.182	30.6	5.082	48.4	1.497	36.2
2007	0.871	23.0	0.322	25.8	4.144	32.4	1.393	30.8	2.794	40.1	1.075	39.7
2008	1.333	23.7	0.413	23.0	3.319	44.3	1.582	54.0				
2009	1.113	27.4	0.460	32.2	2.007	31.8	0.648	31.0				
2010	1.099	18.7	0.304	19.2	2.989	34.5	1.163	32.3				

NOTE: All indices calculated with trawl door and trawl gear conversion factors where appropriate. Winter trawl survey began in 1992 and ended in 2007.

Table A19. NEFSC trawl survey spring and fall survey indices from the FSV Henry B. Bigelow (HBB) and length calibrated, equivalent indices for the FSV Albatross IV (ALB) time series. Indices are the sum of the stratified mean numbers (n) at length. Spring and fall strata sets include offshore strata 1-2, 5-6, 9-10, 25, 69-70, and 73-74 and inshore strata 2,5,8,11,14,17,20,23,26,29,45,46, and 56. The HBB does not sample the shallowest inshore strata (0-18 m, 0-60 ft, 0-10 fathoms). The length calibration factors are for the SNE/MA stock region for the lengths observed in the calibration experiment and include a constant swept area factor of 0.587. The effective total catch number calibration factors vary by year and season, depending on the characteristics of the HBB length frequency distributions.

Year	Spring (n) HBB	HBB CV	Spring (n) ALB	Effective Factor
2009	3.584	25.4	1.113	3.220
2010	3.936	20.2	1.099	3.581
2011				

Year	Autumn (n) HBB	HBB CV	Autumn (n) ALB	Effective Factor
2009	5.909	32.2	2.007	2.944
2010	8.988	35.2	2.989	3.007

Table A20. NEFSC trawl survey spring and fall survey indices at age from the FSV Henry B. Bigelow (HBB) and equivalent indices at age for the FSV Albatross IV (ALB) time series. Indices at age are compiled after the application of length calibration factors including a constant swept area factor of 0.587. The effective catch number at age calibration factors vary by year and season, depending on the characteristics of the HBB length frequency distributions

Spring

2009	1	2	3	4	5	6	7+	Total
HBB	0.48	0.75	1.05	0.53	0.57	0.16	0.05	3.59
ALB	0.07	0.25	0.34	0.18	0.2	0.06	0.01	1.11
HBB/ALB	6.86	3.00	3.09	2.94	2.85	2.67	5.00	3.23

2010	1	2	3	4	5	6	7+	Total
HBB	1.37	0.77	1.03	0.47	0.22	0.07	0.01	3.94
ALB	0.24	0.27	0.34	0.15	0.08	0.02	0.004	1.10
HBB/ALB	5.71	2.85	3.03	3.13	2.75	3.50	2.50	3.57

Fall

2009	1	2	3	4	5	6	7+	Total
HBB	1.49	2.77	0.8	0.5	0.27	0.04	0.035	5.91
ALB	0.54	0.91	0.26	0.17	0.1	0.01	0.009	2.00
HBB/ALB	2.76	3.04	3.08	2.94	2.70	4.00	3.89	2.95

2010	1	2	3	4	5	6	7+	Total
HBB	1.37	3.81	2.24	0.75	0.62	0.06	0.093	8.94
ALB	0.48	1.23	0.74	0.25	0.22	0.02	0.035	2.98
HBB/ALB	2.85	3.10	3.03	3.00	2.82	3.00	2.66	3.01

Table A21. SNE/MA winter flounder mean weight per tow for annual state surveys

Year	MADM Spring	RIDFW Spring	CTDEP Spring
1978	18.24		
1979	18.42	7.72	
1980	15.13	13.57	
1981	16.20	12.13	
1982	15.18	5.23	
1983	20.01	9.52	
1984	14.80	8.43	15.68
1985	11.79	5.93	13.91
1986	10.50	6.47	10.33
1987	9.85	8.14	11.76
1988	6.73	6.02	18.28
1989	8.92	3.09	22.62
1990	5.68	3.07	29.01
1991	3.01	7.38	24.59
1992	8.05	0.95	12.29
1993	8.42	0.22	10.26
1994	12.93	1.67	12.20
1995	7.85	6.04	7.72
1996	9.92	4.45	20.41
1997	9.89	4.57	15.53
1998	8.15	5.00	14.66
1999	4.61	3.66	10.29
2000	6.26	4.52	12.63
2001	3.69	3.56	14.02
2002	1.91	3.29	10.83
2003	5.00	1.56	8.87
2004	2.97	1.85	6.11
2005	4.14	2.05	3.37
2006	3.80	3.45	1.82
2007	3.82	1.96	7.02
2008	1.97	1.63	5.08
2009	3.57	1.11	3.96
2010	5.03	3.24	4.26

Table A22. SNE/MA winter flounder mean number per tow for annual state surveys.

	MADMF Spring	RIDFW Spring	CTDEP Spring CTDEP	NYDEC	NJDFW Ocean	NJDFW Rivers
197	52.00					
197	54.87	83.76				
198	39.35	63.10				
198	47.80	87.97				
198	41.46	31.39				
198	58.14	58.97				
198	38.02	41.64	111.96			
198	39.49	34.97	83.58	4.87		
198	36.78	41.02	63.65			
198	39.16	56.21	79.92	6.10		
198	28.36	34.44	137.59	4.34		
198	27.38	20.88	148.19	17.09		
199	27.72	20.33	223.09	12.43		
199	11.02	41.95	150.20	21.67		
199	28.96	4.40	61.39	79.12		
199	50.40	2.92	63.60	31.35	19.17	
199	50.84	10.25	84.44	22.21	14.06	
199	37.37	32.19	50.12	8.21	30.41	2.82
199	30.92	20.67	110.62	19.23	9.40	3.05
199	38.51	22.28	71.31	10.98	36.02	3.35
199	35.88	19.22	72.91	7.19	18.20	4.25
199	25.98	13.45	41.35	10.99	17.79	3.23
200	24.64	16.32	45.41	2.61	10.12	2.11
200	15.79	12.49	54.50	8.00	13.83	2.84
200	6.70	11.56	43.71	0.42	22.58	2.80
200	17.73	5.56	27.84	1.41	12.52	1.57
200	11.14	11.16	20.46	6.00	14.21	1.27
200	27.02	15.74	16.10		25.67	0.99
200	17.63	15.36	5.59		18.13	
200	16.68	7.33	28.68	1.26	18.58	
200	10.63	7.36	24.11		12.01	
200	14.58	3.67	22.65		13.98	
201	29.84	11.56	20.88		7.99	

Table A23. SNE/MA winter flounder young-of-year indices (age 0 stratified mean number per tow [NYDEC, DEDFW] or haul [RIDFW,CTDEP] or meter^2 [MADMF]) for annual state surveys.

Year	CTDEP	RIDFW	DEDFW	MADMF	NYDEC
1976				0.344	
1977				0.641	
1978				0.366	
1979				0.507	
1980				0.432	
1981				0.340	
1982				0.370	
1983				0.231	
1984				0.323	
1985				0.335	1.52
1986		29.00	0.17	0.325	
1987		11.60	0.09	0.274	2.67
1988	15.46	9.19	0.02	0.184	1.47
1989	1.90	18.92	0.29	0.421	11.20
1990	2.85	21.48	0.63	0.325	8.73
1991	5.23	12.19	0.03	0.267	14.72
1992	11.90	33.33	0.27	0.294	76.87
1993	5.61	5.29	0.04	0.067	17.10
1994	14.23	2.52	0.31	0.148	14.93
1995	10.10	5.64	0.10	0.154	4.10
1996	19.22	6.22	0.04	0.221	16.25
1997	7.47	4.70	0.10	0.392	4.42
1998	9.24	2.56	0.13	0.165	3.11
1999	8.70	14.97	0.07	0.201	7.52
2000	4.33	53.00	0.08	0.347	0.90
2001	1.34	13.73	0.06	0.214	2.31
2002	3.06	18.12	0.01	0.100	0.07
2003	8.07	31.22	0.28	0.197	0.86
2004	10.96	18.72	0.20	0.095	0.50
2005	5.63	5.28	0.02	0.075	
2006	0.93	12.72	0.15	0.163	
2007	4.73	14.17	0.05	0.167	1.11
2008	1.97	11.65	0.02	0.092	
2009	0.78	10.77	0.04	0.083	
2010	0.97	1.52	0.22	0.092	

Table A24. University of Rhode Island Graduate School of Oceanography (URIGSO) trawl survey indices for SNE/MA winter flounder. Indices are annual averages of weekly numbers per tow collected at two stations in Narragansett Bay (Fox Island) and Rhode Island Sound (Whale Rock).

Year	Mean	Year	Mean
1959	59.533	2000	14.644
1960	55.771	2001	16.700
1961	67.592	2002	9.960
1962	73.202	2003	19.706
1963	70.104	2004	25.806
1964	59.721	2005	30.750
1965	95.892	2006	10.819
1966	115.506	2007	8.543
1967	185.566	2008	27.029
1968	203.385	2009	11.538
1969	163.205	2010	12.306
1970	109.335		
1971	71.708		
1972	60.548		
1973	61.403		
1974	54.403		
1975	37.865		
1976	30.721		
1977	41.192		
1978	97.993		
1979	166.719		
1980	141.910		
1981	115.047		
1982	88.296		
1983	186.434		
1984	73.578		
1985	35.036		
1986	25.874		
1987	65.046		
1988	55.210		
1989	36.444		
1990	20.124		
1991	16.796		
1992	11.885		
1993	19.063		
1994	12.439		
1995	57.629		
1996	41.196		
1997	43.050		
1998	26.969		
1999	13.240		

Table A25. VIMS NEAMAP trawl survey aggregate indices for SNE/MA winter flounder. Indices are calculated as stratified geometric mean numbers and biomass (kg) per standard area swept tow.

Season	Number per tow	Number CV (%)	Biomass per tow	Biomass CV (%)
Fall 2007	1.65	15.8	0.97	18.0
Fall 2008	2.32	11.1	1.27	14.1
Fall 2009	2.38	10.1	1.23	14.9
Fall 2010	1.71	13.3	0.92	16.4
Spring 2008	2.54	5.6	1.63	7.4
Spring 2009	2.60	4.8	1.78	5.9
Spring 2010	2.61	4.9	1.80	6.3

Table A26. NEFSC Spring survey: stratified mean number per tow at age for winter flounder in the Southern New England/Mid-Atlantic stock complex. Spring strata set includes offshore strata 1-2, 5-6, 9-10, 25, 69-70, 73-74 and inshore strata 2,5,8,11,14,17,20,23,26,29,45,46,56.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total	7+
1976	0.040	0.450	0.413	0.417	0.122	0.060	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.512	0.011
1977	0.000	0.659	0.418	0.501	0.179	0.012	0.014	0.007	0.013	0.000	0.014	0.000	0.000	0.000	0.000	0.000	1.816	0.034
1978	0.000	0.989	0.910	1.083	0.260	0.033	0.003	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.290	0.013
1979	0.000	0.232	0.558	0.306	0.169	0.016	0.009	0.059	0.000	0.000	0.009	0.000	0.000	0.000	0.000	0.000	1.358	0.068
1980	0.000	1.418	4.549	2.009	0.215	0.071	0.019	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8.284	0.003
1981	0.000	0.740	4.277	3.891	0.452	0.098	0.007	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	9.482	0.016
1982	0.000	1.111	2.605	1.150	0.348	0.117	0.044	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5.407	0.032
1983	0.000	0.400	0.840	1.801	0.871	0.584	0.319	0.062	0.064	0.000	0.000	0.000	0.000	0.000	0.000	0.000	4.940	0.126
1984	0.000	0.171	1.518	1.458	0.525	0.254	0.147	0.062	0.013	0.002	0.006	0.013	0.006	0.000	0.000	0.000	4.173	0.103
1985	0.000	0.424	1.280	2.074	0.480	0.231	0.193	0.110	0.027	0.000	0.000	0.000	0.000	0.000	0.000	0.011	4.830	0.148
1986	0.000	0.074	0.382	1.187	0.287	0.144	0.047	0.013	0.004	0.004	0.004	0.000	0.000	0.000	0.000	0.000	2.147	0.026
1987	0.000	0.176	0.534	0.624	0.230	0.032	0.015	0.004	0.022	0.014	0.000	0.000	0.000	0.000	0.000	0.000	1.651	0.040
1988	0.000	0.068	0.451	0.963	0.349	0.139	0.043	0.021	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.034	0.021
1989	0.000	0.095	0.759	0.872	0.269	0.107	0.002	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.113	0.009
1990	0.000	0.197	0.501	1.062	0.284	0.071	0.031	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.147	0.000
1991	0.000	0.106	0.528	1.200	0.410	0.053	0.013	0.021	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.339	0.029
1992	0.000	0.166	0.270	0.653	0.349	0.051	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.499	0.000
1993	0.000	0.143	0.379	0.225	0.117	0.045	0.005	0.006	0.003	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.925	0.011
1994	0.000	0.202	0.793	0.460	0.101	0.018	0.018	0.008	0.000	0.006	0.000	0.000	0.000	0.000	0.000	0.000	1.606	0.014
1995	0.000	0.170	0.839	0.853	0.205	0.035	0.003	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.111	0.006
1996	0.000	0.077	0.496	0.769	0.173	0.074	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.603	0.000
1997	0.000	0.122	0.436	0.672	0.184	0.067	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.489	0.000
1998	0.000	0.298	1.263	0.601	0.361	0.110	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.644	0.000
1999	0.000	0.451	1.970	1.351	0.369	0.092	0.039	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	4.292	0.020
2000	0.000	0.297	0.787	1.172	0.724	0.236	0.087	0.021	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.326	0.022
2001	0.000	0.200	0.309	0.523	0.450	0.182	0.023	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.690	0.004
2002	0.000	0.047	0.612	0.510	0.283	0.213	0.100	0.041	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.805	0.041
2003	0.000	0.117	0.086	0.331	0.099	0.057	0.040	0.007	0.004	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.746	0.016
2004	0.000	0.309	0.182	0.176	0.312	0.120	0.034	0.030	0.009	0.008	0.000	0.000	0.000	0.000	0.000	0.000	1.180	0.047
2005	0.000	0.093	0.525	0.108	0.196	0.058	0.029	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.019	0.012
2006	0.000	0.330	0.727	0.602	0.151	0.080	0.027	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.917	0.000
2007	0.000	0.056	0.173	0.336	0.212	0.049	0.016	0.014	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.871	0.029
2008	0.000	0.182	0.552	0.365	0.179	0.040	0.014	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.333	0.001
2009	0.000	0.070	0.252	0.337	0.182	0.201	0.059	0.004	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.113	0.014
2010	0.000	0.236	0.265	0.341	0.153	0.076	0.025	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.099	0.004

Table A27. NEFSC Fall survey: stratified mean number per tow at age for winter flounder in the Southern New England/Mid-Atlantic stock complex. Spring strata set includes offshore strata 1-2, 5-6, 9-10, 25, 69-70, 73-74 and inshore strata 2,5,8,11,14,17,20,23,26,29,45,46,56.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total	6+
1976	0.000	0.058	0.835	0.983	0.390	0.261	0.133	0.064	0.104	0.000	0.000	0.000	0.000	0.000	0.000	2.827	0.301
1977	0.009	0.681	2.565	1.872	0.380	0.009	0.004	0.007	0.004	0.004	0.000	0.000	0.000	0.000	0.000	5.534	0.018
1978	0.000	0.586	2.169	1.304	0.315	0.013	0.026	0.013	0.013	0.013	0.000	0.000	0.000	0.000	0.000	4.451	0.064
1979	0.000	4.152	4.458	1.638	0.282	0.053	0.018	0.014	0.014	0.012	0.000	0.000	0.000	0.000	0.000	10.639	0.057
1980	0.000	1.236	5.470	2.880	0.570	0.006	0.006	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	10.176	0.013
1981	0.000	2.225	5.874	2.459	0.398	0.053	0.013	0.022	0.013	0.000	0.000	0.000	0.000	0.000	0.000	11.057	0.048
1982	0.000	0.865	2.291	1.203	0.489	0.062	0.023	0.013	0.013	0.000	0.000	0.000	0.000	0.000	0.000	4.959	0.049
1983	0.000	1.795	4.465	2.380	0.645	0.382	0.102	0.144	0.098	0.019	0.000	0.000	0.000	0.000	0.000	10.031	0.364
1984	0.000	0.178	0.978	1.248	0.312	0.002	0.026	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.748	0.030
1985	0.000	0.132	1.065	0.948	0.311	0.057	0.009	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.537	0.024
1986	0.000	0.249	1.001	0.297	0.039	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.597	0.000
1987	0.000	0.043	0.762	0.391	0.129	0.040	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.365	0.000
1988	0.000	0.044	0.332	0.528	0.223	0.034	0.000	0.007	0.004	0.000	0.000	0.000	0.000	0.000	0.000	1.172	0.012
1989	0.000	0.319	0.831	0.381	0.061	0.022	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.613	0.000
1990	0.000	0.095	1.077	0.913	0.167	0.014	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.267	0.001
1991	0.000	0.045	1.149	0.831	0.109	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.149	0.000
1992	0.000	0.194	1.872	0.969	0.254	0.025	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.320	0.006
1993	0.000	0.383	0.522	0.348	0.066	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.321	0.003
1994	0.000	0.501	2.542	1.236	0.375	0.063	0.046	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	4.763	0.046
1995	0.000	0.399	0.866	0.735	0.115	0.005	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.133	0.014
1996	0.000	0.623	1.488	0.941	0.364	0.072	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.489	0.002
1997	0.009	1.519	3.954	2.871	0.703	0.080	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	9.136	0.000
1998	0.004	1.446	3.139	2.190	0.463	0.050	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	7.299	0.007
1999	0.000	0.427	1.086	1.795	0.583	0.214	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	4.137	0.032
2000	0.000	0.986	2.244	2.460	0.646	0.169	0.012	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	6.527	0.022
2001	0.000	0.516	1.245	1.017	0.350	0.215	0.015	0.030	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.387	0.046
2002	0.018	0.397	4.982	2.819	1.366	0.619	0.212	0.004	0.020	0.000	0.000	0.000	0.000	0.000	0.000	10.438	0.236
2003	0.000	0.480	1.086	1.285	0.499	0.130	0.032	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.527	0.048
2004	0.000	2.212	0.755	0.354	0.350	0.074	0.043	0.025	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.812	0.068
2005	0.000	0.828	2.090	0.942	0.265	0.155	0.090	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	4.379	0.099
2006	0.000	0.455	1.586	0.906	0.225	0.071	0.017	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.264	0.021
2007	0.000	0.675	1.997	1.220	0.193	0.023	0.036	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	4.144	0.036
2008	0.000	0.495	0.803	0.846	0.744	0.336	0.095	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.319	0.095
2009	0.000	0.536	0.914	0.259	0.173	0.099	0.014	0.003	0.000	0.006	0.000	0.003	0.000	0.000	0.000	2.007	0.026
2010	0.004	0.477	1.234	0.744	0.254	0.218	0.022	0.028	0.000	0.007	0.000	0.000	0.000	0.000	0.000	2.989	0.057

Table A28. NEFSC Winter survey: stratified mean number per tow at age for winter flounder in the Southern New England/Mid-Atlantic stock complex (strata set: offshore 1-2, 5-6, 9-10, 69, 73). The Winter survey ended in 2007.

Year	0	1	2	3	4	5	6	7	8+	Total
1992		0.73	0.86	1.09	0.73	0.24	0.02	0.02		3.68
1993		0.56	1.16	0.54	0.18	0.12	0.02	0.01		2.59
1994		0.36	1.16	1.76	0.25	0.28				3.80
1995		0.04	0.75	1.26	0.17					2.22
1996		1.01	0.87	1.55	0.32	0.02				3.78
1997		0.43	1.49	1.32	0.54	0.13				3.91
1998		0.42	3.52	1.95	0.96	0.32				7.17
1999		0.84	5.94	2.23	0.96	0.20	0.16			10.33
2000		0.23	2.82	2.12	0.24	0.16				5.57
2001		1.04	0.55	0.70	0.54	0.22	0.05			3.10
2002		0.08	1.34	0.74	0.15	0.21	0.06	0.21	0.11	2.90
2003		0.09	0.57	1.04	0.25	0.22			0.03	2.20
2004		2.17	1.02	0.43	0.36	0.22	0.09	0.03	0.02	4.34
2005		0.39	2.56	0.36	0.43	0.27	0.04			4.05
2006		0	2.40	1.73	0.51	0.27	0.08	0.07	0.02	5.08
2007		0.02	0.56	1.03	1.03	0.13	0.02			2.79

Table A29. MADMF spring trawl survey mean number per tow at age for winter flounder in the Southern New England/Mid-Atlantic stock complex.

Year	1	2	3	4	5	6	7	8	9+	Total
1978	10.00	9.80	15.86	9.40	3.17	1.10	1.34	0.51	0.82	52.00
1979	4.72	13.18	21.58	9.08	2.99	1.02	0.97	0.47	0.86	54.87
1980	1.65	8.30	14.66	9.23	3.04	0.97	0.80	0.28	0.43	39.36
1981	8.65	9.07	13.66	9.72	3.81	1.20	0.78	0.33	0.58	47.80
1982	3.06	11.88	12.72	8.80	2.66	1.07	0.69	0.18	0.40	41.46
1983	1.71	15.32	17.85	14.11	4.14	2.34	1.12	0.64	0.90	58.14
1984	1.28	9.59	11.82	10.18	3.35	1.22	0.46	0.01	0.12	38.02
1985	3.13	9.98	16.48	6.35	2.48	0.75	0.15	0.07	0.11	39.49
1986	3.27	7.07	19.36	5.69	0.83	0.13	0.19	0.16	0.08	36.78
1987	9.44	7.74	12.35	6.59	2.21	0.22	0.38	0.12	0.11	39.16
1988	3.61	7.02	14.66	2.45	0.35	0.07	0.18	0.00	0.02	28.36
1989	2.26	6.08	12.30	4.68	1.01	0.29	0.28	0.09	0.41	27.38
1990	4.43	11.73	8.03	2.99	0.40	0.02	0.10	0.00	0.02	27.72
1991	1.65	2.88	4.90	1.18	0.24	0.13	0.02	0.00	0.02	11.02
1992	8.06	7.40	6.73	4.21	1.67	0.60	0.07	0.08	0.14	28.96
1993	16.03	18.75	12.02	2.76	0.65	0.14	0.02	0.04	0.00	50.40
1994	12.15	17.35	14.96	4.72	0.62	0.59	0.37	0.05	0.02	50.84
1995	14.31	11.14	8.10	1.93	0.61	0.80	0.28	0.14	0.06	37.37
1996	4.98	10.12	7.72	2.86	2.00	1.46	0.85	0.29	0.64	30.92
1997	10.43	9.30	10.27	4.26	1.32	1.00	0.49	0.75	0.69	38.51
1998	8.62	13.09	7.21	3.51	1.47	1.22	0.41	0.31	0.03	35.88
1999	9.66	8.00	5.81	1.89	0.21	0.25	0.13	0.04	0.00	25.98
2000	6.41	7.78	6.68	1.74	1.09	0.46	0.15	0.23	0.10	24.64
2001	5.47	4.73	2.39	2.02	0.66	0.20	0.13	0.16	0.04	15.79
2002	0.94	3.00	1.55	0.82	0.29	0.08	0.01	0.00	0.00	6.70
2003	4.12	3.78	6.15	2.25	1.14	0.24	0.03	0.01	0.00	17.73
2004	3.46	3.15	1.97	1.67	0.56	0.21	0.09	0.03	0.00	11.14
2005	14.05	8.42	2.68	1.07	0.59	0.11	0.02	0.06	0.00	27.02
2006	3.21	9.61	2.98	1.12	0.32	0.20	0.12	0.06	0.02	17.63
2007	3.69	5.58	5.32	1.63	0.35	0.09	0.02	0.00	0.00	16.68
2008	3.15	4.62	2.06	0.59	0.13	0.02	0.02	0.04	0.00	10.63
2009	2.62	6.04	4.09	1.06	0.68	0.06	0.04	0.00	0.00	14.58
2010	14.20	6.94	5.57	1.74	0.93	0.40	0.07	0.00	0.00	29.84

Table A30. RIDFW spring survey for winter flounder in the Southern New England/Mid Atlantic stock complex.

	Age						
Year	1	2	3	4	5	6	7+
1981	45.67	27.88	12.86	1.27	0.23	0.05	0.02
1982	13.42	9.74	5.02	2.31	0.33	0.11	0.02
1983	29.49	9.79	10.98	6.00	2.13	0.56	0.00
1984	6.67	16.79	13.94	2.96	0.83	0.35	0.10
1985	6.01	15.69	10.35	2.24	0.60	0.08	0.01
1986	11.94	15.63	9.59	2.63	1.14	0.09	0.00
1987	15.30	24.59	13.14	2.66	0.41	0.08	0.04
1988	8.93	12.37	9.53	2.92	0.68	0.01	0.00
1989	4.79	8.20	4.95	2.33	0.51	0.07	0.03
1990	6.46	6.36	4.88	2.16	0.48	0.04	0.06
1991	11.21	14.36	12.00	2.78	0.41	0.10	0.11
1992	1.30	0.95	1.17	0.75	0.20	0.04	0.00
1993	2.32	0.35	0.17	0.06	0.02	0.00	0.00
1994	2.84	4.56	1.97	0.63	0.19	0.04	0.03
1995	9.36	11.36	9.87	1.47	0.13	0.00	0.00
1996	3.11	8.36	7.47	1.56	0.15	0.03	0.00
1997	4.90	8.77	6.86	1.48	0.26	0.00	0.00
1998	2.11	9.47	5.90	1.60	0.13	0.01	0.00
1999	1.71	6.52	4.26	0.82	0.09	0.06	0.00
2000	2.88	4.98	5.51	2.19	0.66	0.10	0.00
2001	2.46	3.47	3.67	2.23	0.63	0.02	0.01
2002	1.60	4.76	3.21	1.24	0.54	0.15	0.06
2003	1.72	0.86	1.76	0.50	0.30	0.28	0.14
2004	5.47	3.97	1.03	0.44	0.12	0.09	0.04
2005	8.86	2.41	1.73	1.38	0.79	0.43	0.14
2006	2.07	4.72	5.24	2.24	0.74	0.30	0.05
2007	1.19	1.12	2.03	1.62	0.86	0.43	0.08
2008	3.29	1.00	1.00	1.12	0.67	0.22	0.06
2009	0.37	1.17	0.80	0.70	0.47	0.12	0.04
2010	3.24	2.68	3.13	1.24	1.06	0.18	0.03

Table A31. University of Rhode Island Graduate School of Oceanography (URIGSO) trawl survey abundance indices at age for winter flounder in the Southern New England/Mid Atlantic stock complex.

	Age										
Year	1	2	3	4	5	6	7	8	9	10+	Total
1985	2.085	18.311	12.148	1.935	0.557	0.000	0.000	0.000	0.000	0.000	35.036
1986	6.871	13.847	4.225	0.829	0.081	0.018	0.004	0.000	0.000	0.000	25.875
1987	16.691	35.862	10.745	1.535	0.196	0.018	0.000	0.000	0.000	0.000	65.046
1988	22.348	24.000	7.816	0.952	0.038	0.000	0.057	0.000	0.000	0.000	55.210
1989	19.739	24.181	2.397	0.930	0.118	0.029	0.010	0.005	0.000	0.000	47.408
1990	6.218	10.333	2.182	0.749	0.098	0.005	0.021	0.019	0.000	0.000	19.624
1991	7.813	5.843	2.548	0.473	0.066	0.053	0.000	0.000	0.000	0.000	16.796
1992	5.812	4.168	1.353	0.465	0.082	0.006	0.000	0.000	0.000	0.000	11.885
1993	9.032	8.757	0.896	0.298	0.060	0.019	0.000	0.000	0.000	0.000	19.063
1994	4.522	6.218	1.502	0.165	0.018	0.013	0.000	0.000	0.000	0.000	12.439
1995	34.710	13.644	7.262	1.377	0.210	0.257	0.133	0.036	0.000	0.000	57.630
1996	14.216	19.679	5.407	1.106	0.432	0.249	0.081	0.010	0.014	0.002	41.196
1997	18.056	15.554	6.974	1.561	0.411	0.235	0.086	0.102	0.046	0.128	43.153
1998	7.495	13.729	3.904	1.251	0.306	0.215	0.038	0.027	0.004	0.000	26.969
1999	7.082	3.068	2.068	0.724	0.093	0.147	0.053	0.005	0.000	0.000	13.241
2000	7.465	3.768	2.284	0.819	0.111	0.143	0.054	0.000	0.000	0.000	14.644
2001	4.102	0.898	0.268	0.109	0.023	0.027	0.006	0.000	0.000	0.000	5.434
2002	5.386	3.178	0.992	0.341	0.057	0.007	0.000	0.000	0.000	0.000	9.961
2003	14.160	4.302	0.821	0.262	0.118	0.033	0.000	0.010	0.000	0.000	19.707
2004	18.364	6.465	0.503	0.322	0.094	0.038	0.019	0.000	0.000	0.000	25.806
2005	23.593	6.307	0.661	0.156	0.033	0.000	0.000	0.000	0.000	0.000	30.750
2006	5.195	4.036	1.215	0.339	0.026	0.008	0.000	0.000	0.000	0.000	10.820
2007	4.408	2.881	0.953	0.238	0.059	0.004	0.000	0.000	0.000	0.000	8.543
2008	18.744	7.412	0.715	0.148	0.010	0.000	0.000	0.000	0.000	0.000	27.029
2009	3.645	5.917	1.652	0.212	0.106	0.006	0.000	0.000	0.000	0.000	11.538
2010	7.729	3.164	1.098	0.249	0.048	0.017	0.001	0.000	0.000	0.000	12.306

Table A32. CTDEP spring survey for winter flounder in the Southern New England/Mid Atlantic stock complex.

Year	1	2	3	4	5	6	7	8	9	10	11	12+	Total
1984	8.21	44.01	31.83	20.96	4.23	1.23	0.67	0.74	0.04	0.01	0.03	0.00	111.96
1985	4.11	28.46	32.88	14.17	2.33	0.82	0.45	0.19	0.11	0.04	0.02	0.00	83.57
1986	6.69	26.00	15.53	12.26	2.05	0.50	0.24	0.24	0.10	0.01	0.03	0.00	63.65
1987	7.32	44.69	14.56	5.05	6.55	1.28	0.11	0.24	0.13	0.00	0.00	0.00	79.93
1988	14.49	71.87	39.10	8.59	1.83	1.46	0.16	0.04	0.02	0.02	0.00	0.00	137.59
1989	13.56	78.43	41.23	10.85	2.84	0.98	0.14	0.09	0.06	0.01	0.00	0.00	148.19
1990	11.31	131.52	64.97	8.97	4.09	1.96	0.19	0.05	0.00	0.02	0.00	0.00	223.09
1991	8.52	66.99	60.39	9.31	4.05	0.80	0.14	0.00	0.00	0.00	0.01	0.00	150.21
1992	6.80	31.32	12.78	8.97	1.10	0.36	0.05	0.00	0.00	0.00	0.00	0.00	61.38
1993	19.11	19.87	15.46	4.81	3.24	0.80	0.15	0.11	0.04	0.01	0.00	0.00	63.59
1994	9.57	64.14	5.86	3.01	1.14	0.49	0.17	0.05	0.01	0.01	0.00	0.00	84.45
1995	14.35	23.69	9.77	1.36	0.63	0.20	0.08	0.02	0.02	0.00	0.00	0.00	50.12
1996	11.46	59.07	24.17	14.41	0.97	0.28	0.14	0.06	0.04	0.01	0.00	0.00	110.61
1997	12.53	25.53	19.41	9.45	3.76	0.51	0.07	0.03	0.01	0.01	0.01	0.00	71.31
1998	11.22	32.40	12.23	12.67	3.15	0.99	0.14	0.02	0.07	0.00	0.00	0.00	72.90
1999	6.56	12.42	11.27	6.09	3.20	1.14	0.61	0.04	0.01	0.02	0.00	0.00	41.35
2000	7.11	16.66	8.40	7.70	3.42	1.53	0.31	0.26	0.01	0.01	0.00	0.01	45.42
2001	8.45	19.60	10.85	8.06	5.46	1.28	0.68	0.05	0.08	0.00	0.00	0.00	54.51
2002	6.27	19.90	9.56	4.43	1.95	1.02	0.35	0.11	0.03	0.10	0.00	0.00	43.72
2003	2.47	7.83	8.71	4.79	1.95	0.77	0.82	0.29	0.07	0.14	0.00	0.00	27.84
2004	6.34	3.84	3.49	3.88	1.91	0.64	0.21	0.11	0.03	0.01	0.00	0.01	20.46
2005	7.06	6.18	0.84	0.81	0.67	0.21	0.16	0.10	0.05	0.01	0.01	0.00	16.10
2006	1.14	2.60	1.10	0.19	0.14	0.17	0.09	0.01	0.09	0.03	0.02	0.00	5.58
2007	2.98	10.83	10.70	3.10	0.61	0.15	0.11	0.12	0.04	0.01	0.01	0.00	28.66
2008	11.48	3.48	4.19	4.12	0.65	0.12	0.04	0.03	0.01	0.00	0.00	0.00	24.12
2009	7.56	11.21	1.02	1.31	1.21	0.22	0.06	0.04	0.00	0.01	0.00	0.00	22.64
2010	6.64	8.45	3.94	0.71	0.57	0.44	0.11	0.01	0.00	0.01	0.00	0.00	20.88

Table A33. NYDEC Peconic Bay Small Mesh Trawl Survey for winter flounder in the Southern New England/Mid Atlantic stock complex. No sampling in 1986, 2005, 2006, survey ended in 2007

	AGE			
Year	0	1	2+	Total
1985	1.52	3.05	0.30	4.87
1986				
1987	2.67	3.31	0.12	6.10
1988	1.47	2.57	0.31	4.34
1989	11.20	5.54	0.35	17.09
1990	8.73	3.44	0.26	12.43
1991	14.72	6.35	0.59	21.67
1992	76.87	2.04	0.20	79.12
1993	17.10	14.12	0.12	31.35
1994	14.93	6.96	0.32	22.21
1995	4.10	3.84	0.27	8.21
1996	16.25	2.84	0.15	19.23
1997	4.42	6.45	0.11	10.98
1998	3.11	3.80	0.29	7.19
1999	7.52	3.25	0.22	10.99
2000	0.90	1.56	0.15	2.61
2001	2.31	5.52	0.17	8.00
2002	0.07	0.17	0.19	0.42
2003	0.86	0.45	0.09	1.41
2004	0.50	5.38	0.11	6.00
2005				
2006				
2007	1.11	0.11	0.04	1.26

Table A34. NJDFW Ocean survey (April) for winter flounder in the Southern New England/Mid Atlantic stock complex.

	AGE							
Year	1	2	3	4	5	6	7+	Total
1993	5.10	6.50	2.50	2.40	1.70	0.40	0.57	19.17
1994	3.70	4.20	3.90	1.40	0.40	0.30	0.16	14.06
1995	8.00	10.10	8.60	2.40	0.90	0.30	0.11	30.41
1996	0.60	2.90	2.60	1.90	0.90	0.30	0.20	9.40
1997	16.60	5.40	6.10	6.00	1.50	0.30	0.12	36.02
1998	4.50	3.90	4.80	3.30	1.20	0.40	0.10	18.20
1999	2.40	2.20	5.90	3.10	2.90	0.70	0.59	17.79
2000	0.70	0.30	2.10	3.30	2.00	0.90	0.82	10.12
2001	3.90	0.60	1.30	2.70	3.80	0.70	0.83	13.83
2002	5.81	3.21	4.55	2.22	2.80	2.16	1.83	22.58
2003	2.08	1.10	4.79	1.24	1.09	0.87	1.35	12.52
2004	6.48	0.72	1.42	2.08	0.56	1.38	1.57	14.21
2005	4.97	10.04	2.55	2.76	2.61	1.32	1.42	25.67
2006	0.64	2.49	9.43	3.23	0.62	0.75	0.97	18.13
2007	3.80	0.67	4.33	6.09	1.51	0.62	1.56	18.58
2008	5.57	1.59	0.83	1.75	1.69	0.21	0.37	12.01
2009	2.84	4.35	3.54	1.34	1.48	0.33	0.10	13.98
2010	0.75	1.59	2.63	1.50	0.94	0.37	0.21	7.99

Table A35. NJDFW Rivers survey (March-May) for winter flounder in the Southern New England/Mid Atlantic stock complex. The Rivers Survey ended in 2005.

	AGE							
Year	1	2	3	4	5	6	7+	Total
1995	0.60	0.30	1.40	0.40	0.10	0.01	0.01	2.82
1996	0.30	0.90	0.70	0.70	0.20	0.10	0.15	3.05
1997	1.10	0.40	0.90	0.40	0.40	0.10	0.05	3.35
1998	1.90	0.90	0.40	0.70	0.20	0.10	0.05	4.25
1999	0.20	0.50	1.40	0.50	0.40	0.10	0.13	3.23
2000	0.40	0.20	0.40	0.80	0.20	0.10	0.01	2.11
2001	1.40	0.30	0.20	0.40	0.40	0.10	0.04	2.84
2002	1.21	0.48	0.49	0.18	0.27	0.13	0.04	2.80
2003	0.05	0.22	0.90	0.18	0.03	0.10	0.09	1.57
2004	0.67	0.02	0.10	0.29	0.05	0.00	0.14	1.27
2005	0.42	0.24	0.17	0.02	0.09	0.02	0.03	0.99

Table A36. VIMS NEAMAP trawl survey indices at age for SNE/MA winter flounder. Indices are calculated as stratified geometric mean numbers per standard area swept tow.

Spring

	1	2	3	4	5	6	7+	Total
2008	1.48	1.36	0.80	1.11	0.45	0	0	5.20
2009	0.63	1.89	1.05	0.49	0.77	0	0	4.83
2010	1.00	1.50	1.63	0.56	0.28	0	0	4.97

Fall

	1	2	3	4	5	6	7+	Total
2007	1.16	0.57	0.75	0.17	0.13	0	0	2.78
2008	2.11	0.72	0.48	0.40	0.08	0	0	3.79
2009	1.79	1.56	0.17	0.17	0.05	0	0	3.74
2010	1.24	0.91	0.60	0.05	0.03	0	0	2.83

Table A37. Summarization of retrospective relative errors (percent) in F and SSB for ADAPT VPA and ASAP SCAA model BASE and SPLIT configurations incorporating “ramps” and “steps” in the assumed value for instantaneous natural mortality (M). The smallest ranges (from positive to negative errors in percent) for each model are highlighted in bold.

VPA

BASE	Error F	Error SSB
M= 0.2	-53 to -28	+105 to +29
M = 0.3	-49 to -21	+86 to +27
Step 0.3-0.45	**-33 to -1**	+47 to +6
Step 0.3-0.6	+32 to -11	+19 to -9
Ramp (1994) 0.3-0.6	+42 to -8	**+7 to -18**
Ramp (2000) 0.3-0.6	+22 to -22	+33 to -12

ASAP

BASE	Error F	Error SSB
M= 0.2	-52 to -23	+72 to +27
M = 0.3	-38 to -13	+42 to +12
Step 0.3-0.45	-19 to -8	+18 to +7
Step 0.3-0.6	+20 to -4	-10 to +4
Ramp (1994) 0.3-0.6	+29 to 0	**-13 to 0**
Ramp (2000) 0.3-0.6	**-12 to +1**	+17 to +1

VPA

SPLIT	Error F	Error SSB
M= 0.2	-26 to +16	+57 to +1
M = 0.3	**-23 to +21**	+51 to +5
M= 0.45	-18 to +31	**+37 to -3**
M = 0.6	-8 to +55	+17 to -14

ASAP

SPLIT	Error F	Error SSB
M= 0.2	-45 to -20	+58 to +24
M = 0.3	-38 to -16	+46 to +17
M= 0.45	-23 to -9	+25 to +9
M = 0.6	**-12 to -2**	**+13 to +5**

Table A38. Summary Assessment results for SNE/MA winter flounder from the final ASAP CAT10 model configuration.

Year	Fishing Mortality (age 4-5)	Spawning Stock (metric tons)	Recruitment age 1 (millions)
1981	0.73	19,392	71,581
1982	0.61	20,108	63,113
1983	0.69	18,093	64,782
1984	0.84	15,948	43,197
1985	1.09	11,500	37,470
1986	0.87	9,087	43,484
1987	1.02	7,500	35,777
1988	1.16	6,205	34,914
1989	1.06	5,413	34,040
1990	0.88	5,479	20,447
1991	1.03	5,762	15,437
1992	0.89	4,977	17,117
1993	0.95	3,941	24,841
1994	0.66	3,990	18,385
1995	0.57	5,732	24,687
1996	0.56	6,481	20,118
1997	0.57	7,510	28,272
1998	0.48	7,753	22,122
1999	0.47	8,213	15,453
2000	0.56	8,941	12,809
2001	0.70	8,124	15,110
2002	0.63	6,045	7,454
2003	0.55	5,555	7,507
2004	0.46	4,911	15,790
2005	0.37	4,505	14,182
2006	0.42	5,194	8,259
2007	0.34	6,221	7,541
2008	0.24	5,850	13,494
2009	0.09	5,729	8,749
2010	0.05	7,076	8,711

Table A39. Environmental variables used in the SDWG response to TOR 5 and their source.

Variable	Abbreviation		Stocks	Source
Southern New England Air Temperature	aSNE	three 2 monthly periods	SNE	http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html
Georges Bank Air Temperature	aGB	three 2 monthly periods	GBK	http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html
Gulf of Maine Air Temperature	aGOM	three 2 monthly periods	GOM	http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html
Woods Hole Coastal Water Temperature	WH	three 2 monthly periods	GBK, SNE	http://www.nefsc.noaa.gov/epd/ocean/MainPage/ioos.html
Boothbay Harbor Coastal Water Temperature	BH	three 2 monthly periods	GOM	http://www.nefsc.noaa.gov/epd/ocean/MainPage/ioos.html
Atlantic Multidecadal Oscillation	AMO	0 year lag	GBK, GOM, SNE	http://www.cdc.noaa.gov/Correlation/amon.us.long.data
North Atlantic Oscillation (DJFM)	NAO	0, 1, and 2 year lags	GBK, GOM, SNE	http://www.cgd.ucar.edu/cas/jhurrell/Data/naodjfmindex.asc
Gulf Stream Index – Joyce and Zhang (2010)	GS-J	0 year lag	GBK GOM, SNE	Terry Joyce (pers. comm.)
Gulf Stream Index – Taylor and Stephens (1998)	GS-PLY	0 year lag	GBK, GOM, SNE	http://www.pml-gulfstream.org.uk/Web2009.pdf

Table A40. Akaike Information Criteria (AIC) statistics for the top ten ranked models for each stock.

Stock	Model Rank	Model	Variable	AICc	delta	weight	cumulative weight
Southern New England	1	BH env M2	aSNE-JF	505.12	0.00	0.214	0.214
	2	BH env M2	GS-J-0	505.62	0.50	0.166	0.380
	3	BH env M1	aSNE-JF	505.79	0.66	0.153	0.533
	4	BH env M3	aSNE-JF	506.15	1.03	0.128	0.661
	5	BH env M2	AMO-0	507.47	2.35	0.066	0.727
	6	BH env M3	AMO-0	508.00	2.88	0.051	0.778
	7	BH env M1	AMO-0	508.05	2.93	0.049	0.827
	8	BH env M1	GS-J-0	509.17	4.05	0.028	0.855
	9	BH env M3	GS-J-0	509.21	4.09	0.028	0.883
	10	BH env M1	WH-JF	509.47	4.35	0.024	0.907
Georges Bank	1	BH std M	none	496.04	0.00	0.082	0.082
	2	BH env M3	aGB-JF	496.76	0.72	0.057	0.139
	3	BH env M1	aGB-MJ	496.95	0.91	0.052	0.191
	4	BH env M2	aGB-MJ	496.96	0.92	0.052	0.243
	5	BH env M3	GS-PML-0	497.29	1.25	0.044	0.287
	6	BH env M2	GS-J-0	497.55	1.51	0.039	0.326
	7	BH env M1	GS-J-0	497.56	1.51	0.039	0.365
	8	BH env M2	WH-MJ	498.04	2.00	0.030	0.395
	9	BH env M1	WH-MJ	498.06	2.02	0.030	0.425
	10	BH env M2	NAO-0	498.15	2.11	0.029	0.454
Gulf of Maine	1	BH env M2	aGOM-JF	423.39	0.00	0.108	0.108
	2	BH env M1	aGOM-JF	423.50	0.10	0.103	0.211
	3	BH env M2	aGOM-MJ	424.72	1.33	0.056	0.267
	4	BH env M2	BH-JF	424.83	1.44	0.053	0.320
	5	BH env M1	aGOM-MJ	424.84	1.45	0.052	0.372
	6	BH env M1	BH-JF	424.86	1.47	0.052	0.424
	7	BH std M	none	424.97	1.58	0.049	0.473
	8	BH env M2	aGOM-MA	425.04	1.64	0.048	0.521
	9	BH env M1	aGOM-MA	425.13	1.74	0.045	0.566
	10	BH env M3	BH-JF	425.63	2.24	0.035	0.601

Table A41. Model weights, explained variance and evidence ratios for best environmentally-explicit models compared to best standard model.

Stock	Model	Variable	W	r^2	Evidence Ratio
Southern New England	BH env M2	aSNE-JF	0.214	0.74	105.8
	BH std M	None	0.002	0.60	
Georges Bank	BH env M3	aGB-JF	0.057	0.07	0.7
	BH std M	None	0.082	0.00	
Gulf of Maine	BH env M2	aGOM-JF	0.108	0.21	2.2
	BH std M	None	0.003	0.07	

Table A42. Results of Beverton-Holt stock recruitment model fits for the Southern New England stock. The lognormal deviate ($\frac{\sum(\ln(R)-\ln(\hat{R}))^2}{n-1}$), mean environmental term, and standard deviation of the environmental term for the environmentally-explicit model are provided.

	No prior – standard model	No prior – environmental model aSNE-JF	Prior a=50,409,200 standard model	Prior a=50,409,200 environmental model
b	0.3482	0.2777	0.1879	0.2842
a	2.4433e-6	2.2278e-5	1.9836e-5	1.9840e-5
c	NA	0.6203	NA	0.6129
$ae^{c\bar{E}}$	NA	8.2171e-6	NA	7.4048e-6
Asym Rec	409,280,000	121,700,000	50,414,000	135,050,000
lognormal deviate	0.2464	0.1963		
$\bar{E}$		-1.6079		
σ_E		1.6654		

Table A43. Summary of stock-recruitment model fits for the final CAT10 model and alternative STEPM models with future M = 0.3 and M = 0.6. Models judged to fit best with feasible results in bold.

ASAP CAT10	No Prior	**Prior h**	Prior R
FMSY	0.235	**0.310**	0.300
SSBMSY	446,946	**33,820**	30,284
MSY	96,216	**9,763**	8,441
h	0.529	**0.636**	0.621
NegLL	306.009	**307.595**	317.827
AIC	618.977	**621.828**	621.814
BIC	622.119	**624.970**	624.956

ASAP STEPM 0.3	**No Prior**	Prior h	Prior R
FMSY	**0.325**	0.35	0.365
SSBMSY	**42,770**	32,683	26,953
MSY	**13,423**	11,071	9,530
h	**0.665**	0.690	0.707
NegLL	**303.707**	303.143	314.928
AIC	**614.373**	614.721	615.601
BIC	**617.515**	617.863	618.743

ASAP STEPM 0.6	**No Prior**	Prior h	Prior R
FMSY	**0.145**	0.820	0.13
SSBMSY	**6,899**	2,702	6,953
MSY	**981**	2,224	885
h	**0.303**	0.680	0.293
NegLL	**303.707**	310.900	314.225
AIC	**614.373**	629.949	614.595
BIC	**317.515**	633.091	617.737

Table A44. Summary of Yield Per Recruit (YPR) and Spawning Stock Biomass per Recruit (SSBR) analysis to estimate 40% Maximum Spawning Potential (MSP) reference point proxies for the final CAT10 model and alternative STEPM models with future M = 0.3 and M = 0.6.

ASAP CAT10	
Fmax	Undefined
F40%	0.327
YPR	0.178
SSBR	0.579
SSB40%	29,045
MSY40%	8,903
ASAP STEPM 0.3	
Fmax	Undefined
F40%	0.323
YPR	0.181
SSBR	0.580
SSB40%	31,311
MSY40%	9,765
ASAP STEPM 0.6	
Fmax	Undefined
F40%	0.652
YPR	0.083
SSBR	0.128
SSB40%	6,926
MSY40%	4,489

Table A45. Summary of 2008 GARM-III (NEFSC 2008) and current assessment candidate Biological Reference Points (BRPs) and status evaluation for SNE/MA winter flounder. BRPs and status evaluation for final ASAP CAT10 model in bold italics.

GARM-III VPA SPLIT M = 0.2	
Fmax	0.713
F40%	0.248
SSB40%	38,761
MSY40%	9,742
F2007	0.649
SSB2007	3,368
F2007/F40%	2.62
SSB2007/SSB40%	0.09

ASAP CAT10 M = 0.3	
FMSY	***0.290***
SSBMSY	***43,661***
MSY	***11,728***
F2010	***0.051***
SSB2010	***7,076***
F2010/FMSY	***0.18***
SSB2010/SSBMSY	***0.16***
F40%	0.327
SSB40%	29,045
MSY40%	8,903
F2010/F40%	0.16
SSB2010/MSY40%	0.24

ASAP STEPM M = 0.3	
FMSY	0.325
SSBMSY	42,770
MSY	13,423
F2010	0.087
SSB2010	4,144
F2010/FMSY	0.27
SSB2010/SSBMSY	0.10
F40%	0.323
SSB40%	31,311
MSY40%	9,765
F2010/F40%	0.27
SSB2010/MSY40%	0.13

ASAP STEPM M = 0.6	
FMSY	0.145
SSBMSY	6,899
MSY	981
F2010	0.087
SSB2010	4,144
F2010/FMSY	0.60
SSB2010/SSBMSY	0.60
F40%	0.652
SSB40%	6,926
MSY40%	4,489
F2010/F40%	0.13
SSB2010/MSY40%	0.60

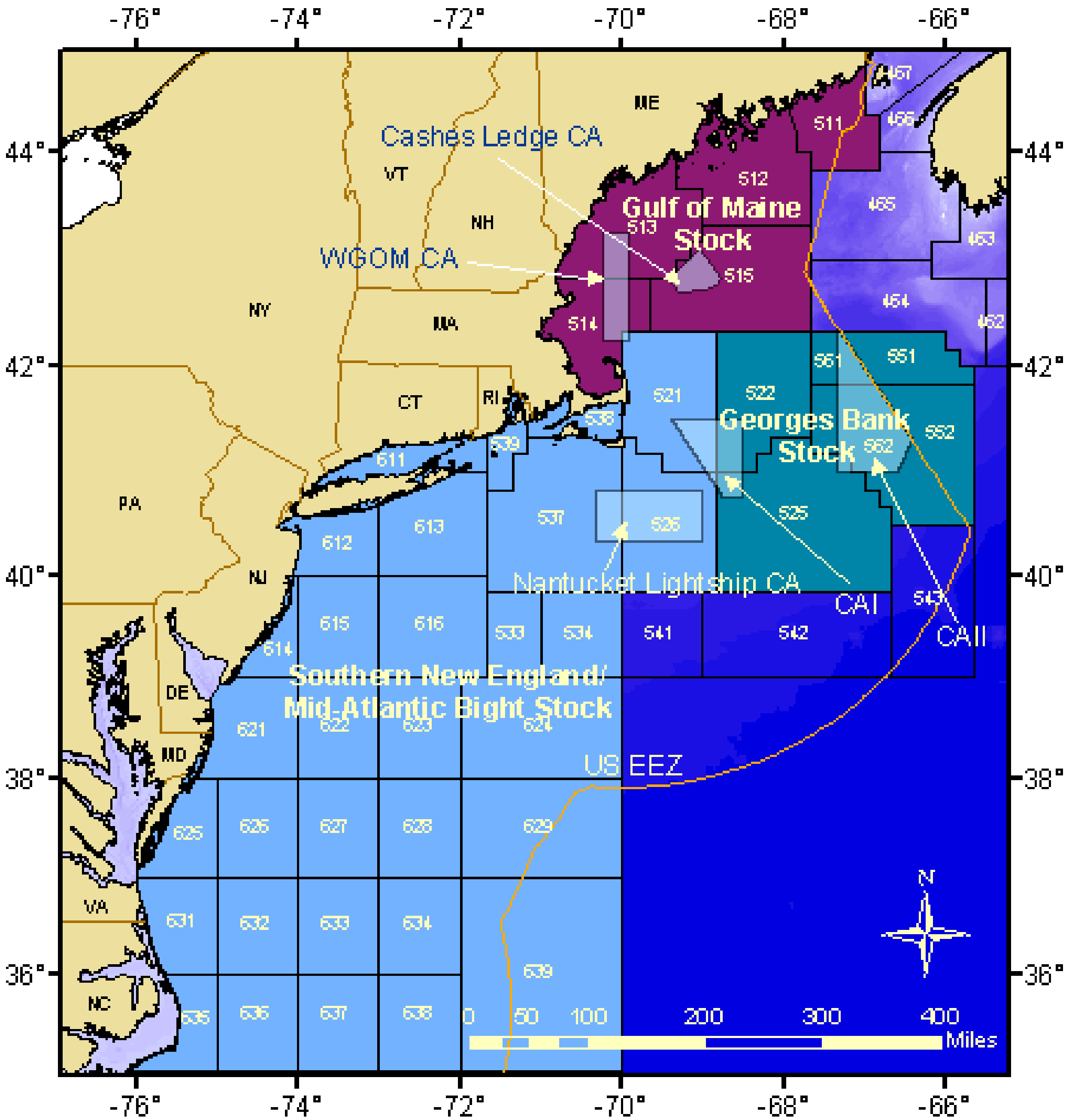

Figure 11.1. Statistical areas used to define the Gulf of Maine, Georges Bank, and Southern New England/Mid-Atlantic Bight winter flounder stocks.

Figure A1. Statistical areas used to define winter flounder stocks. The Southern New England/Mid-Atlantic (SNE/MA) stock complex includes areas 521, 526, 533-539, and 611-639.

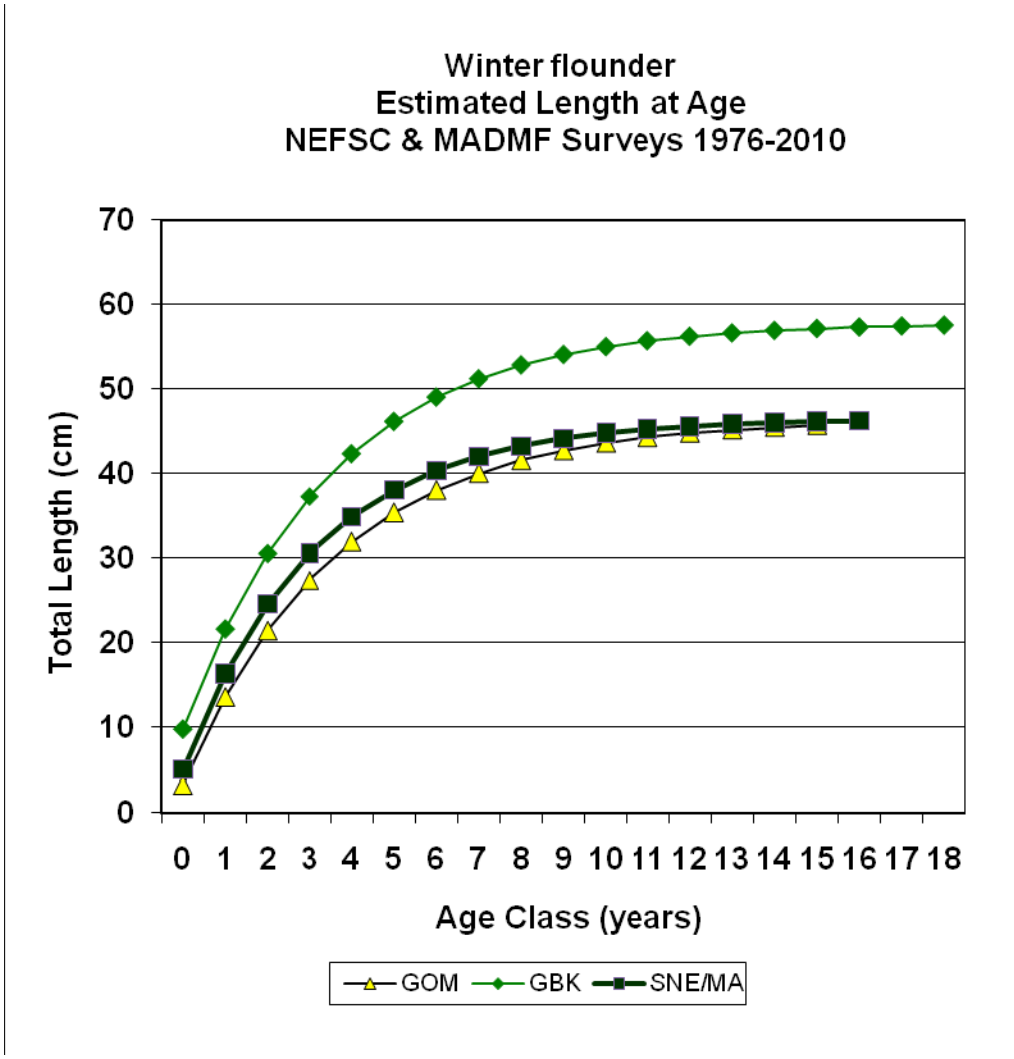

Figure A2. Estimated length at age (von Beertalanffy growth) for winter flounder stocks: NEFSC and MADMF trawl survey age-length data for 1976-2010.

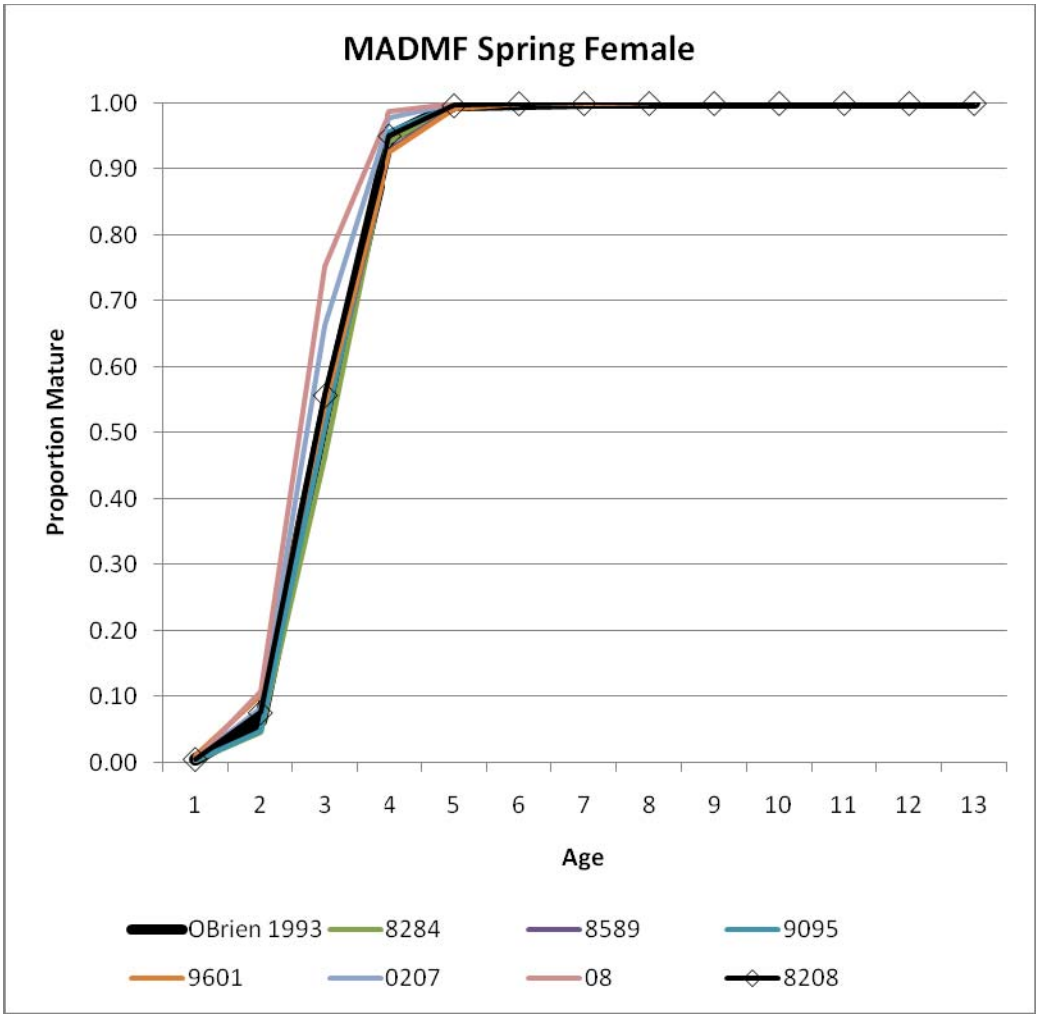

Figure A3. Maturity ogives (probit function) derived from MADMF Spring trawl survey data for SNE/MA winter flounder. The O'Brien et al. (1993) proportions from the MADMF Spring 1985-1989 data have been used in all previous assessments.

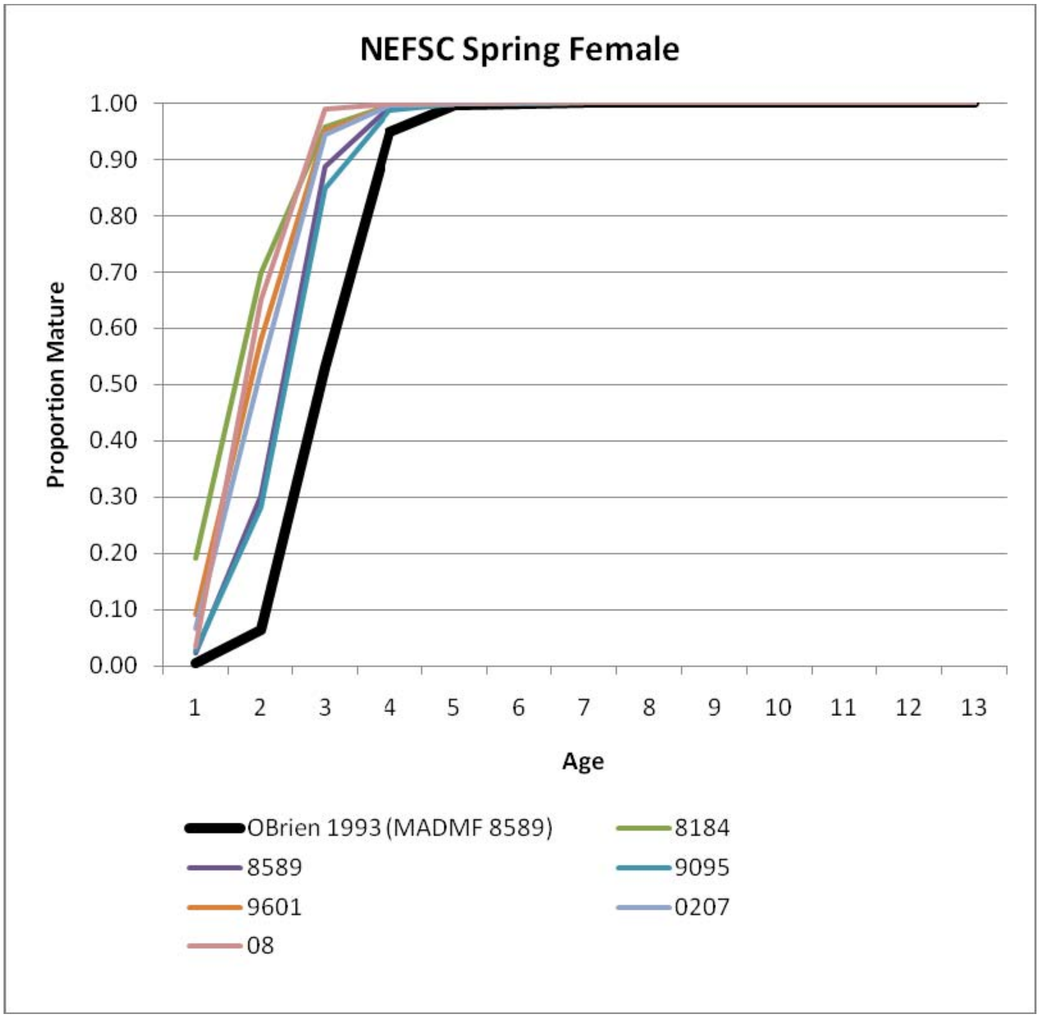

Figure A4. Maturity ogives (probit function) derived from NEFSC Spring trawl survey data for SNE/MA winter flounder. The O'Brien et al. (1993) proportions from the MADMF Spring 1985-1989 data have been used in all previous assessments.

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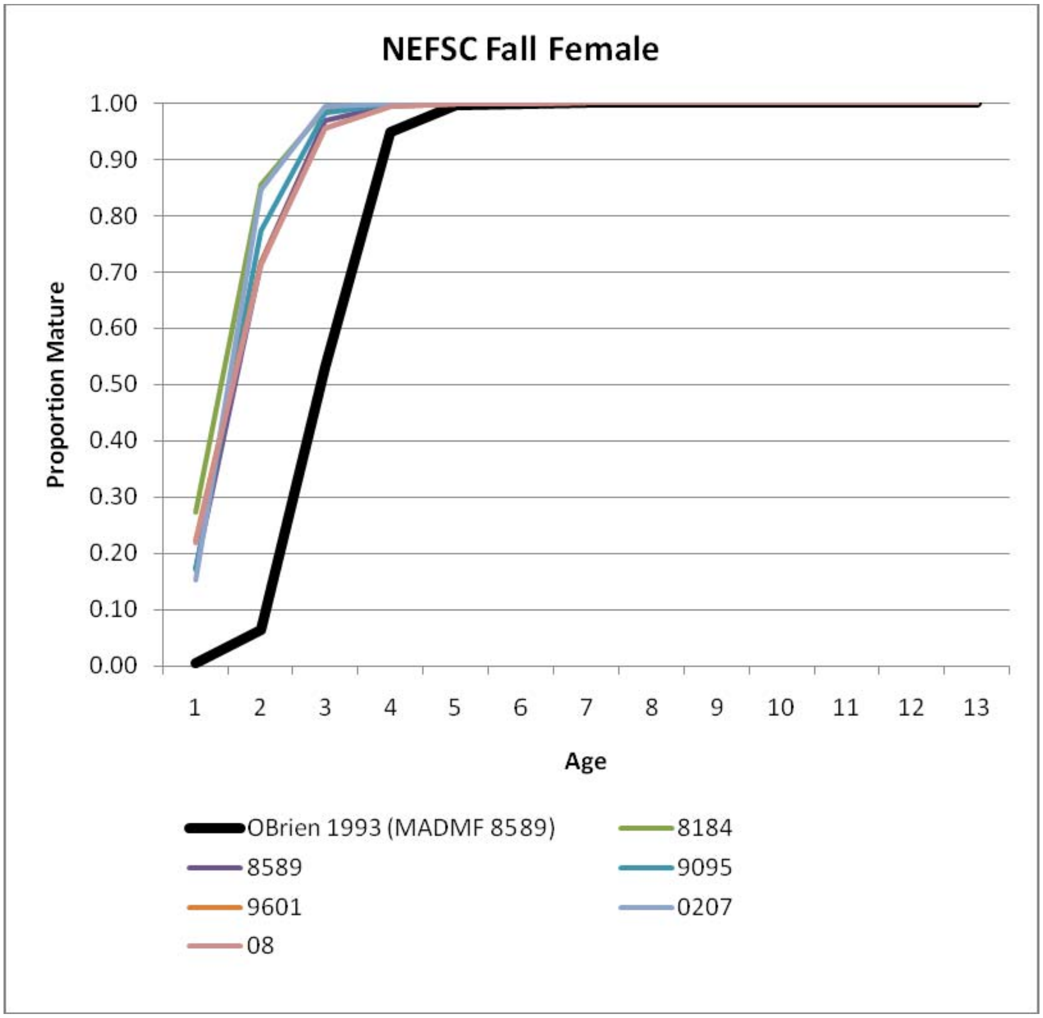


Figure A5. Maturity ogives (probit function) derived from NEFSC Fall trawl survey data for SNE/MA winter flounder. The O'Brien et al. (1993) proportions from the MADMF Spring 1985-1989 data have been used in all previous assessments.

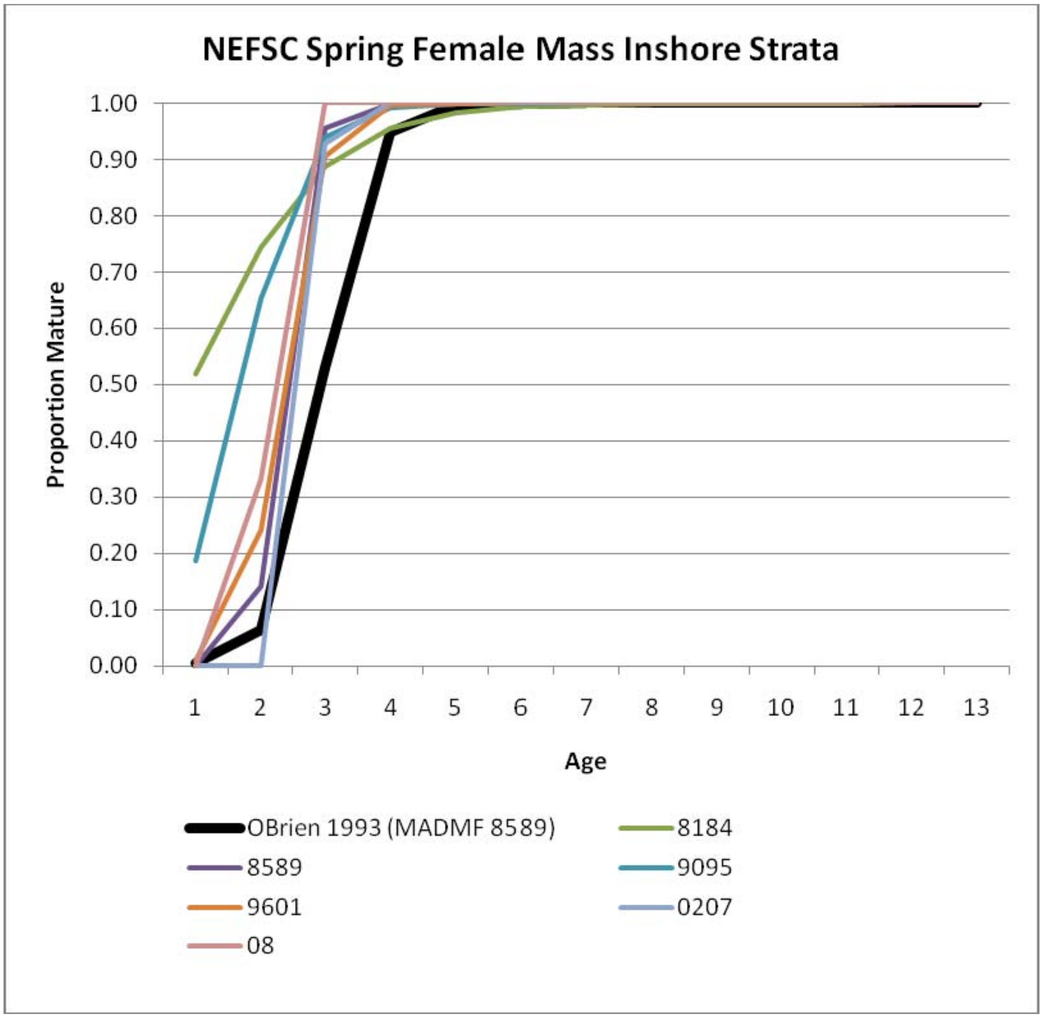


Figure A6. Maturity ogives (probit function) derived from NEFSC Spring trawl survey data for SNE/MA winter flounder, for Massachusetts waters Inshore survey strata. The O'Brien et al. (1993) proportions from the MADMF Spring 1985-1989 data have been used in all previous assessments.

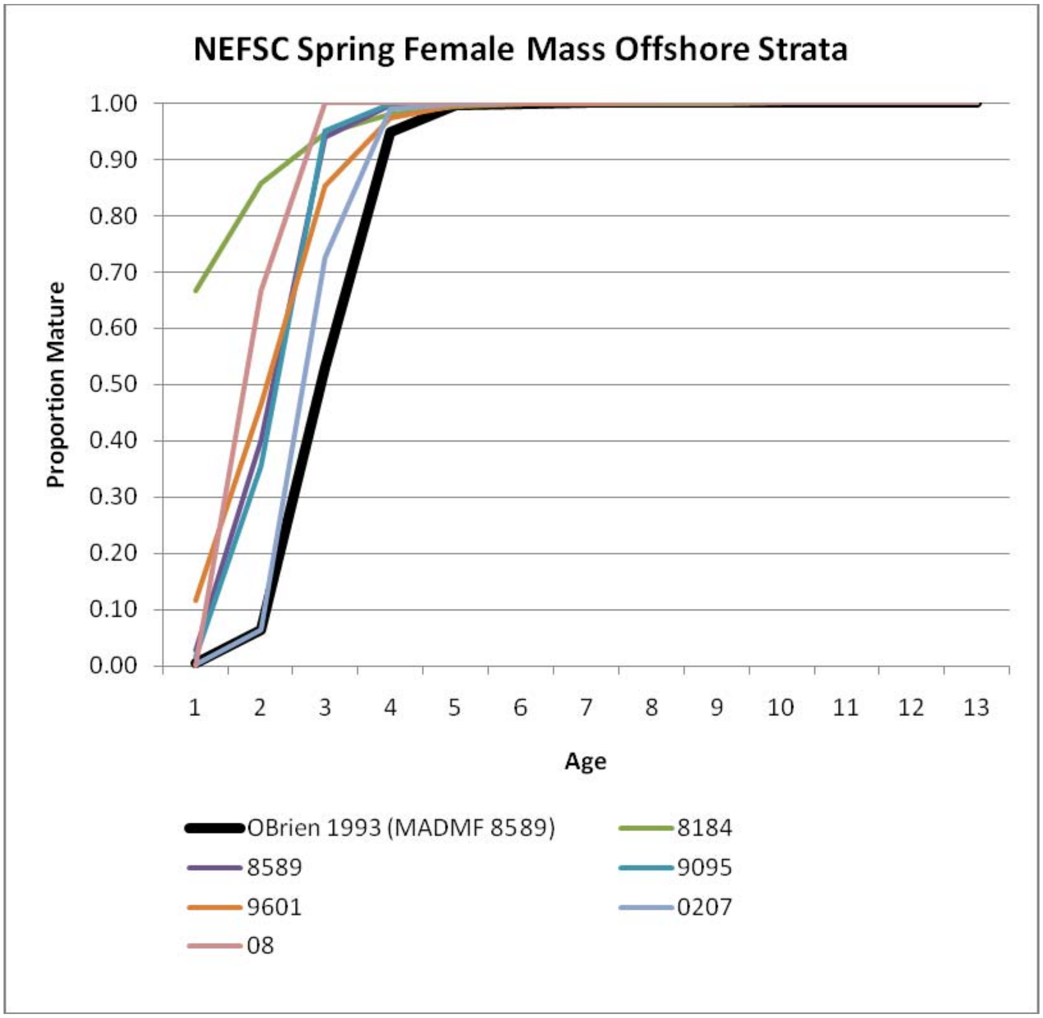
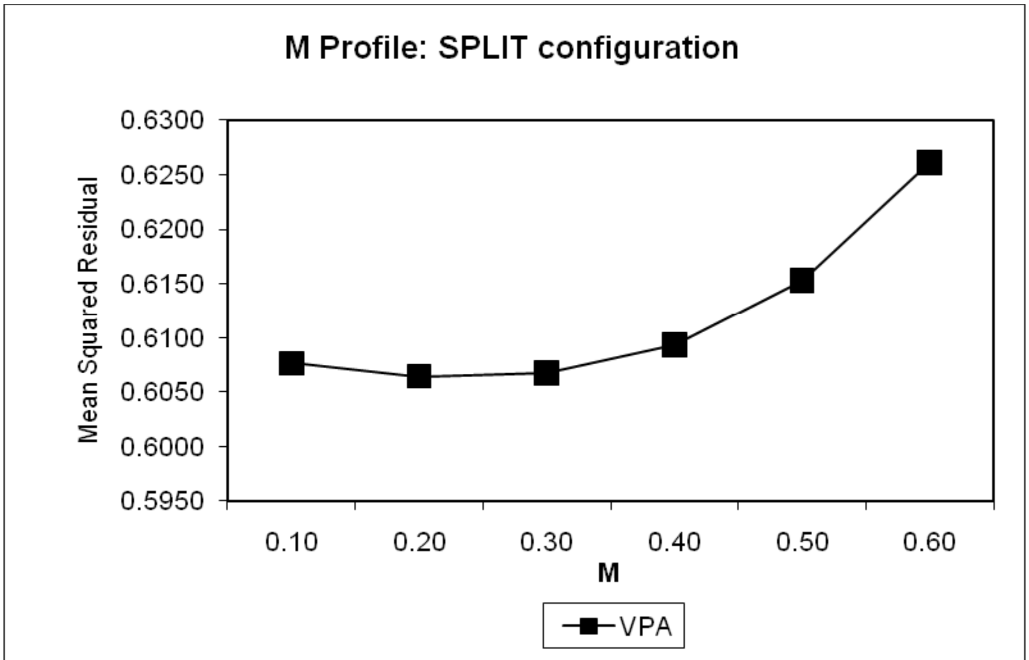


Figure A7. Maturity ogives (probit function) derived from NEFSC Spring trawl survey data for SNE/MA winter flounder, for Massachusetts waters Offshore survey strata. The O'Brien et al. (1993) proportions from the MADMF Spring 1985-1989 data have been used in all previous assessments.



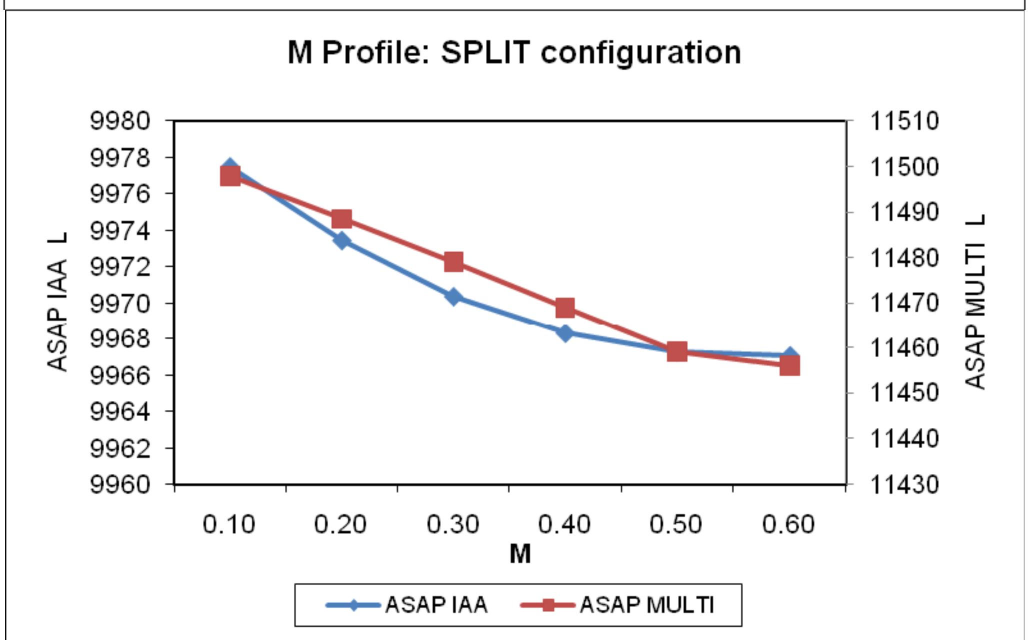


Figure A8. Profiles in mean squared residual for preliminary ADAPT VPA models for M values ranging from 0.1 to 0.6 (top panel). Profiles in likelihood of initial ASAP SCAA model runs (in two different calibration survey configurations) for M values ranging from 0.1 to 0.6 (bottom panel).

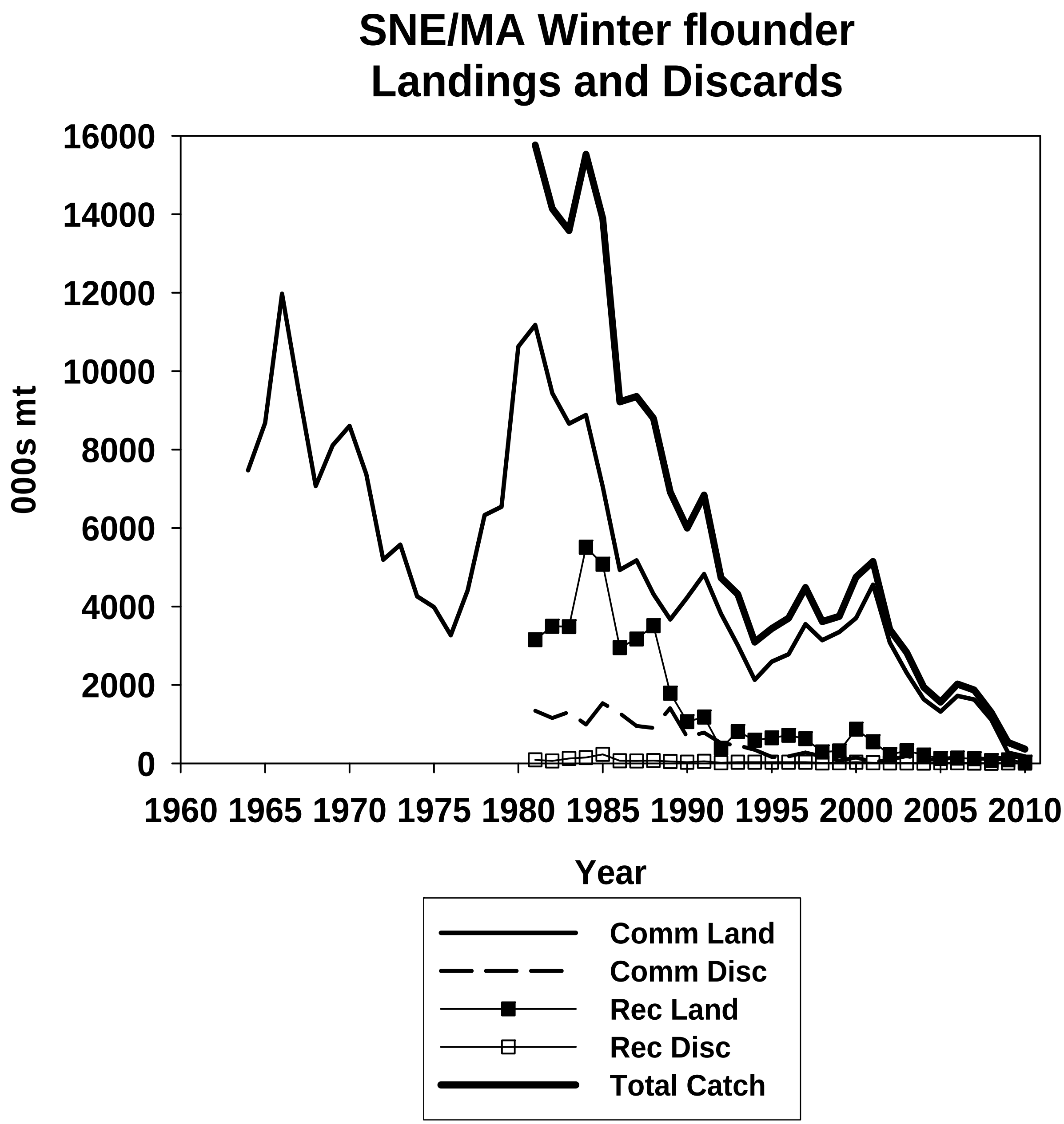


Figure A9. Commercial landings (1964-2010), commercial discards (1981-2010) recreational landings (1981-2010), recreational discards (1981-2010) and total fishery catch (1981-2010) for the SNE/MA winter flounder stock complex.

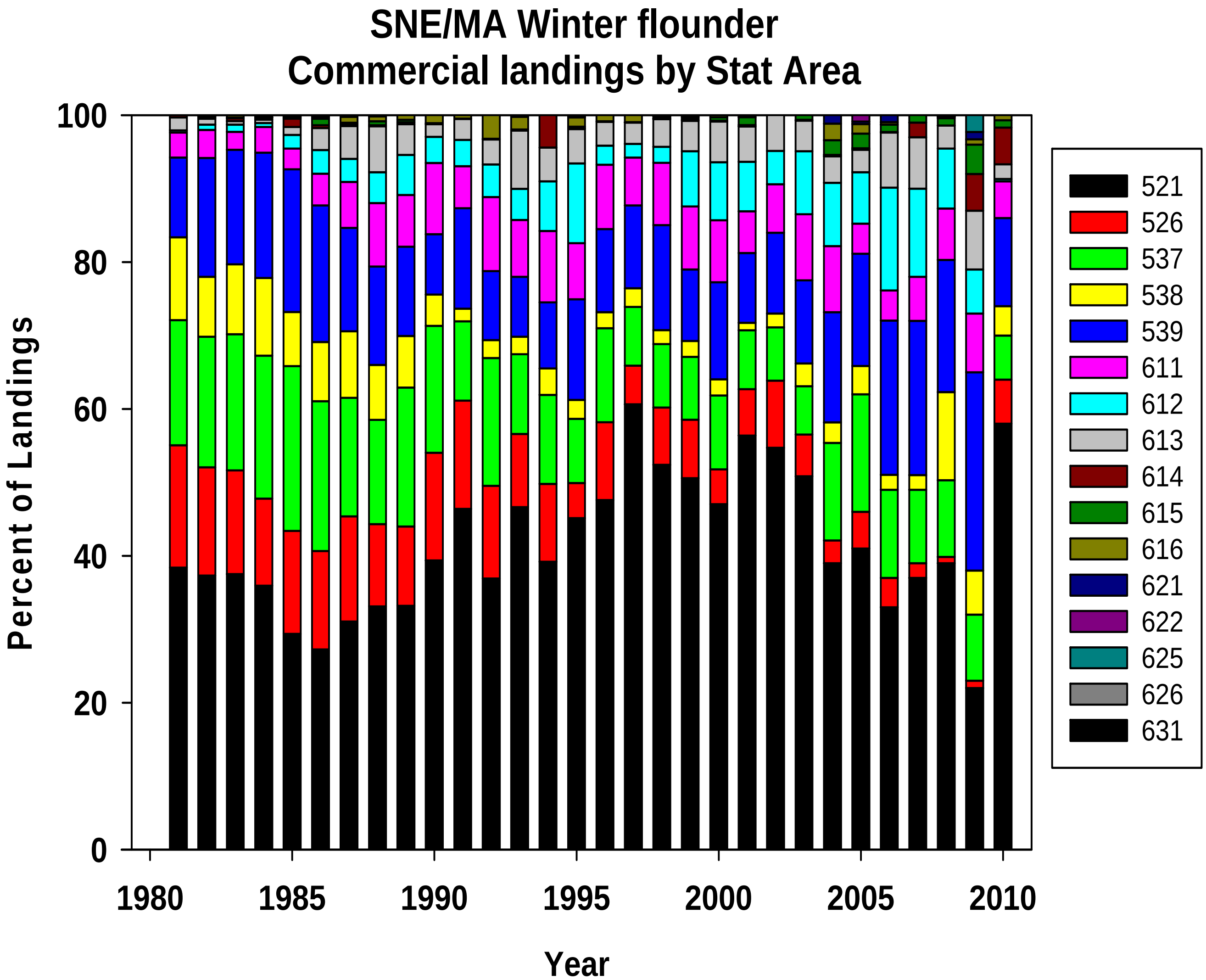


Figure A10. Commercial fishery landings of SNE/MA winter flounder by statistical area.

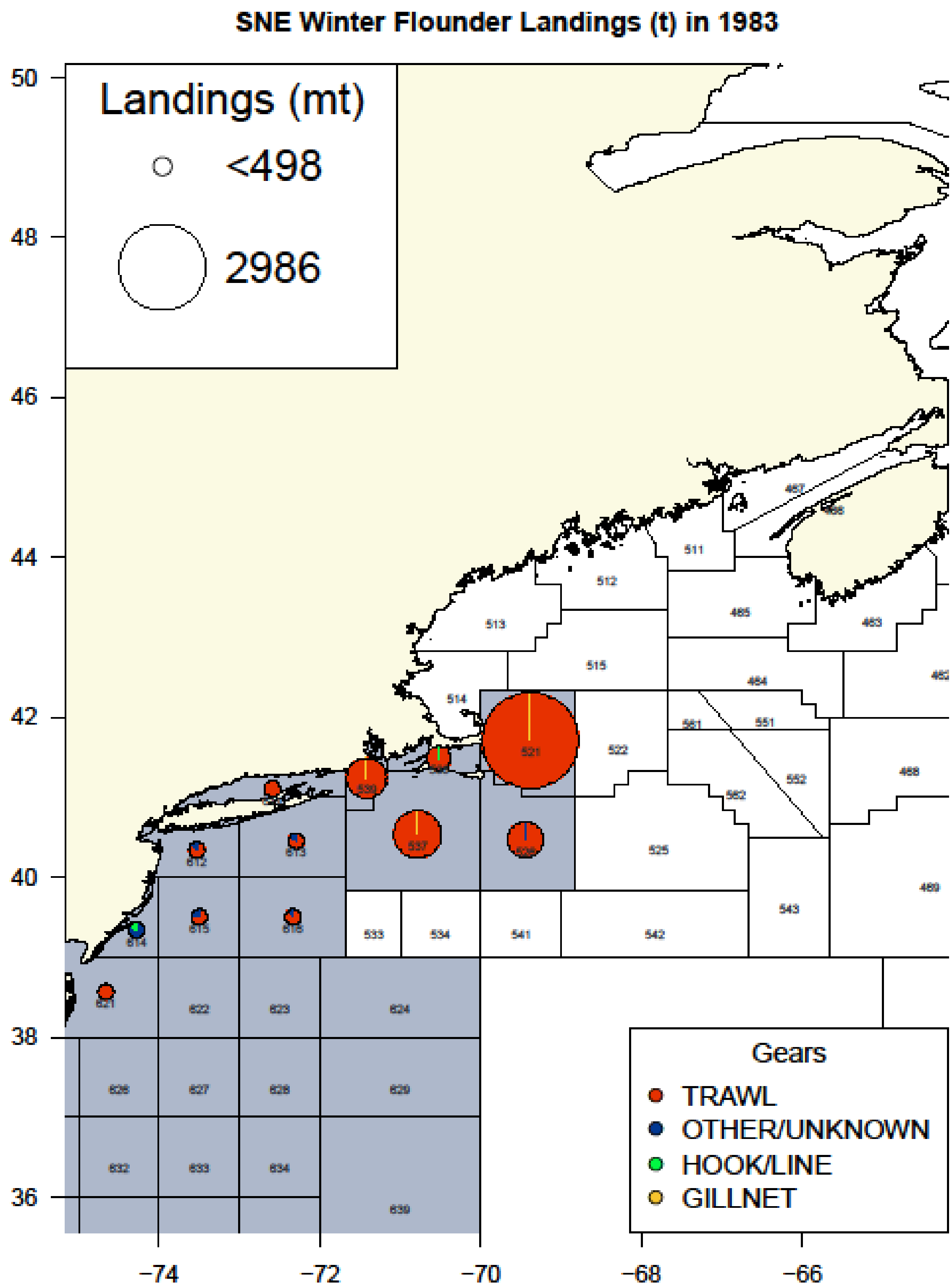


Figure A11. Commercial fishery landings of SNE/MA winter flounder in 1983 by statistical area.

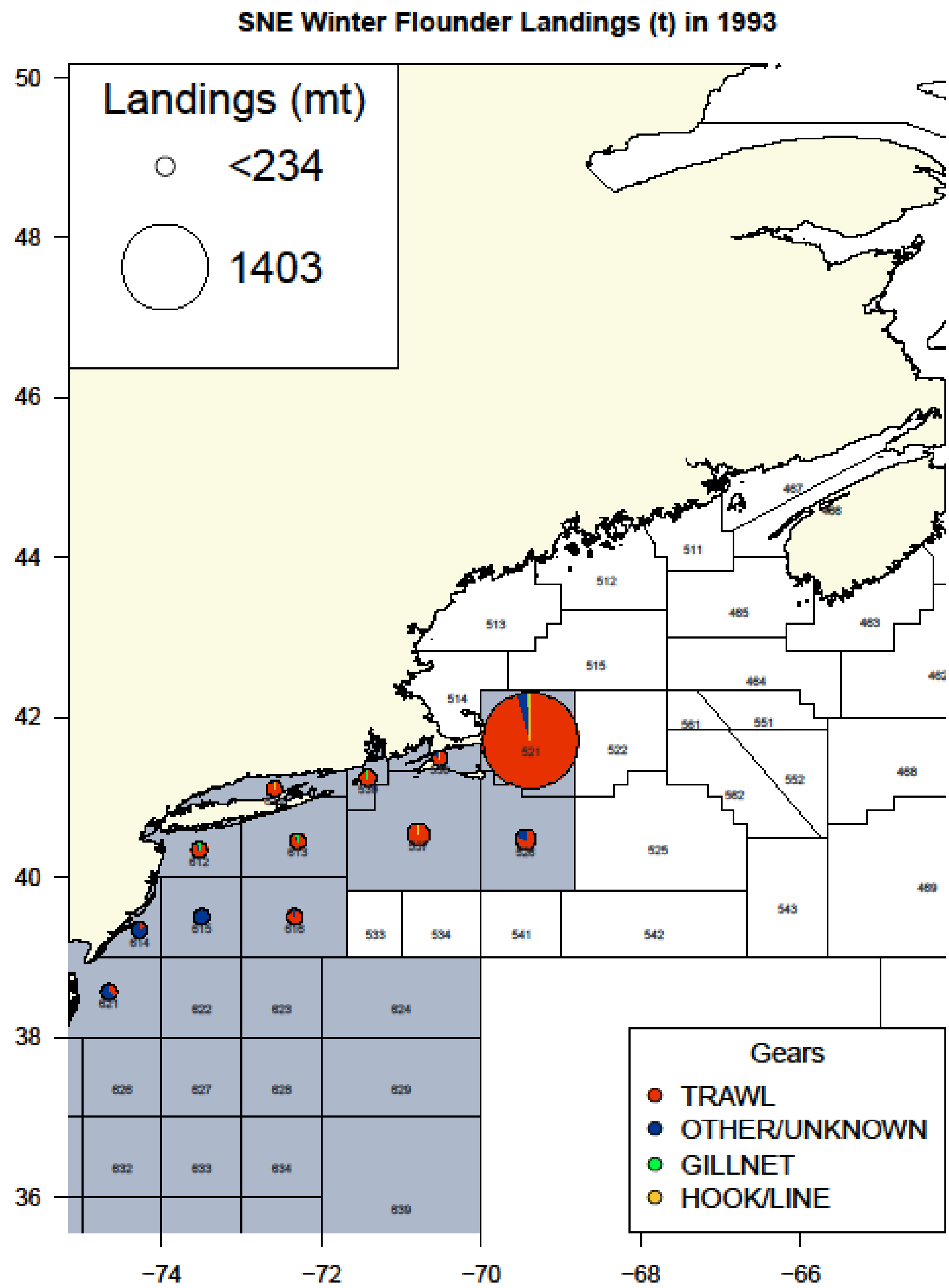


Figure A12. Commercial fishery landings of SNE/MA winter flounder in 1993 by statistical area.

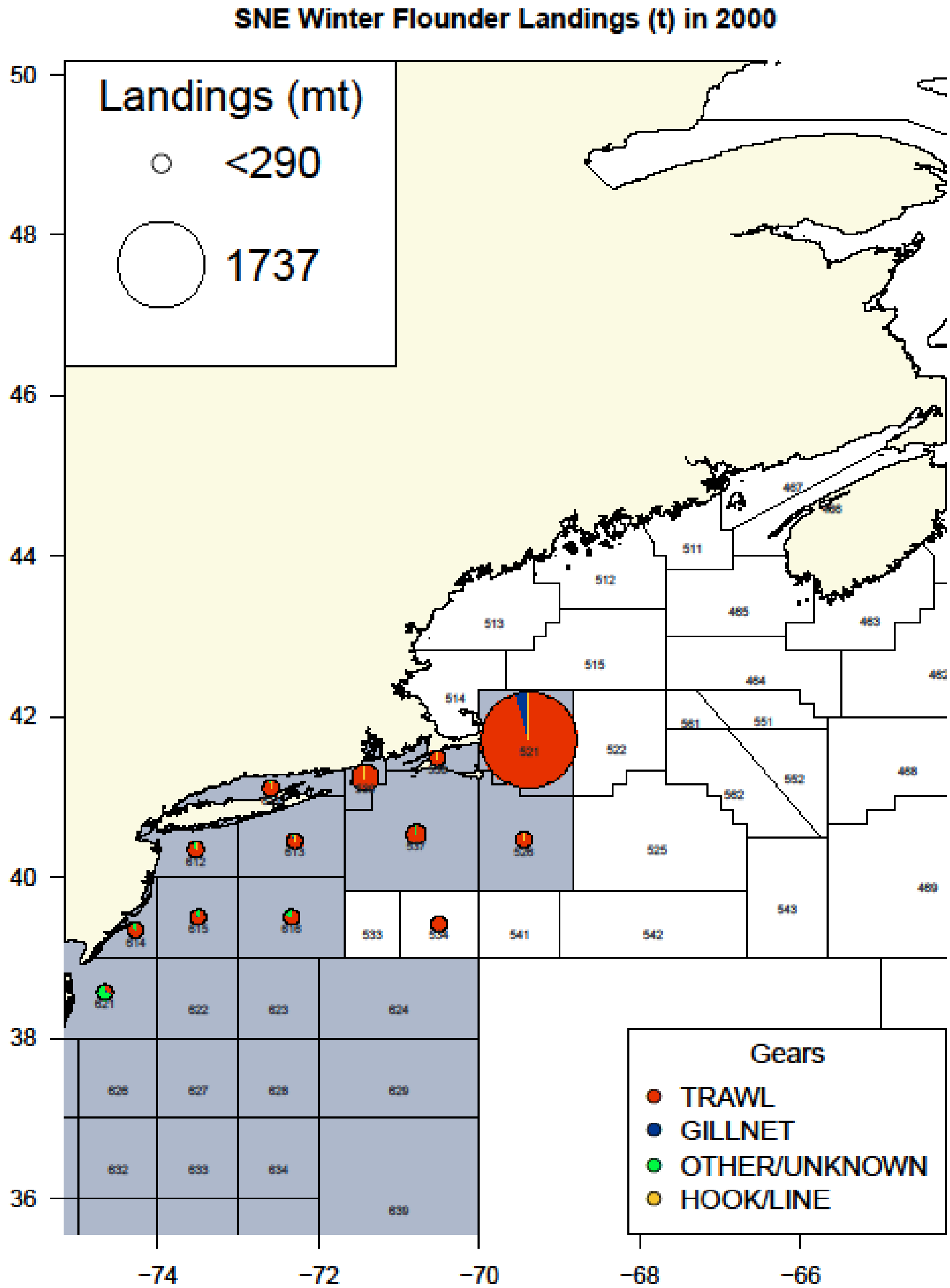


Figure A13. Commercial fishery landings of SNE/MA winter flounder in 2000 by statistical area.

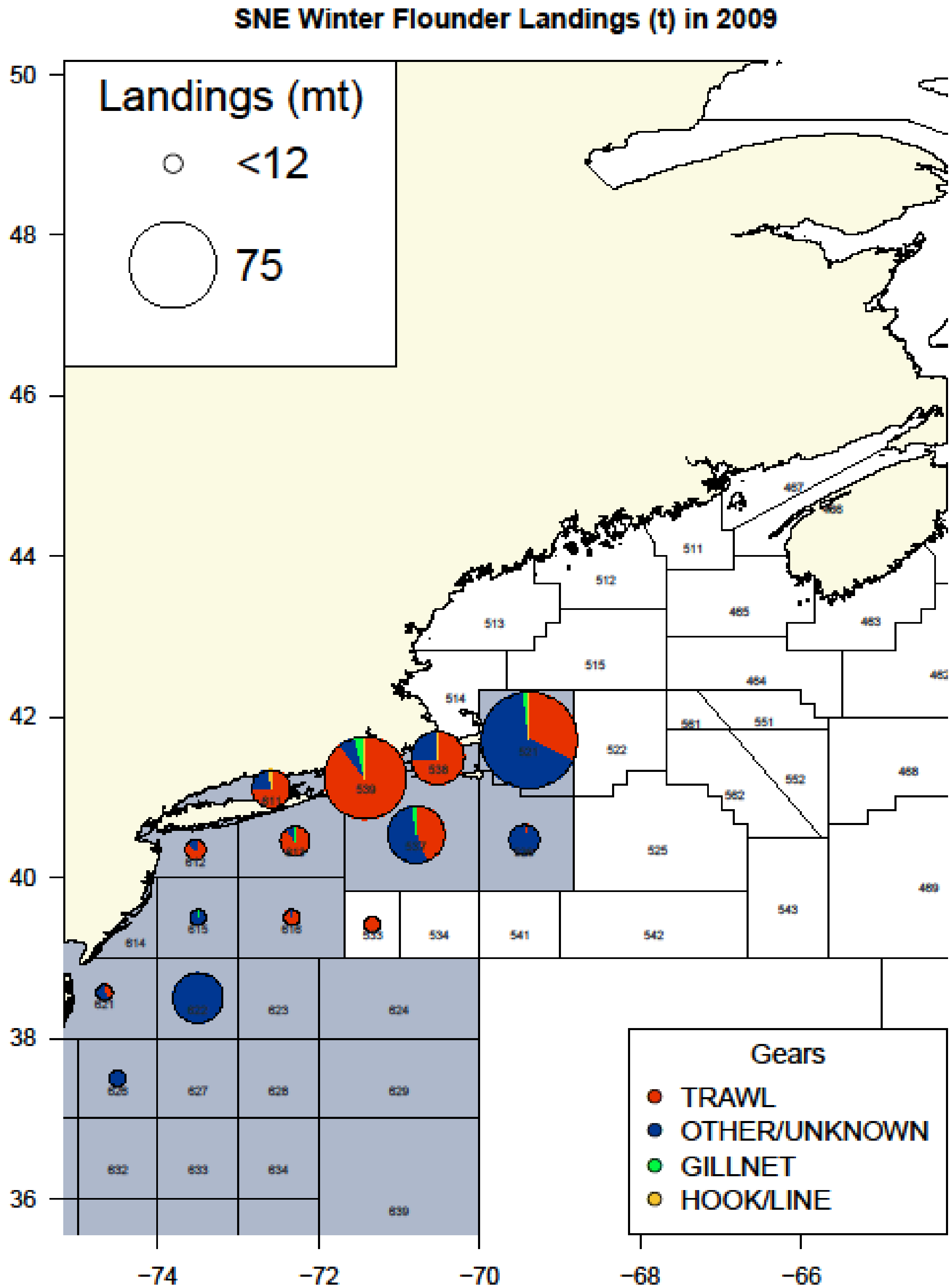


Figure A14. Commercial fishery landings of SNE/MA winter flounder in 2009 by statistical area.

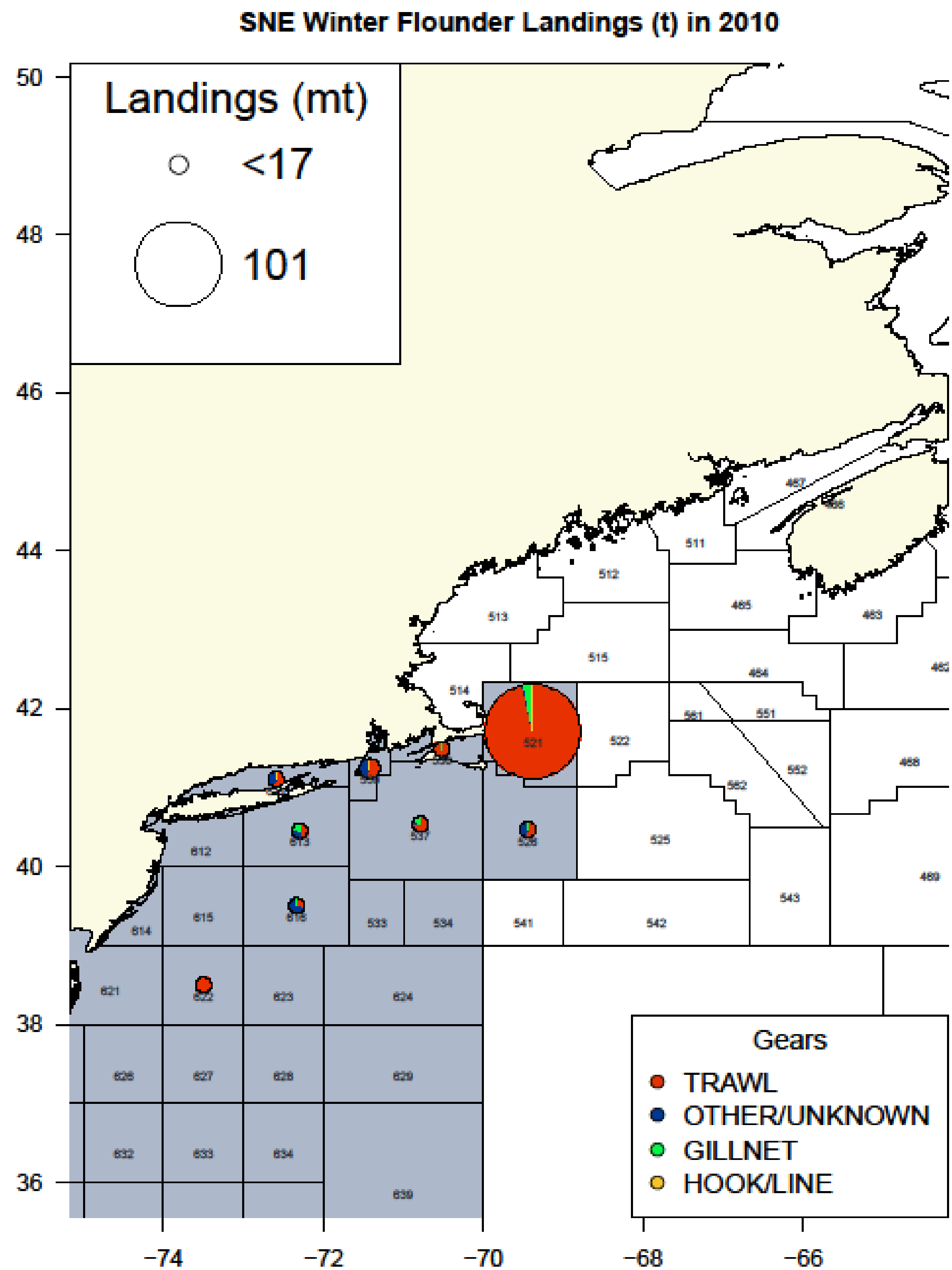


Figure A15. Commercial fishery landings of SNE/MA winter flounder in 2010 by statistical area.

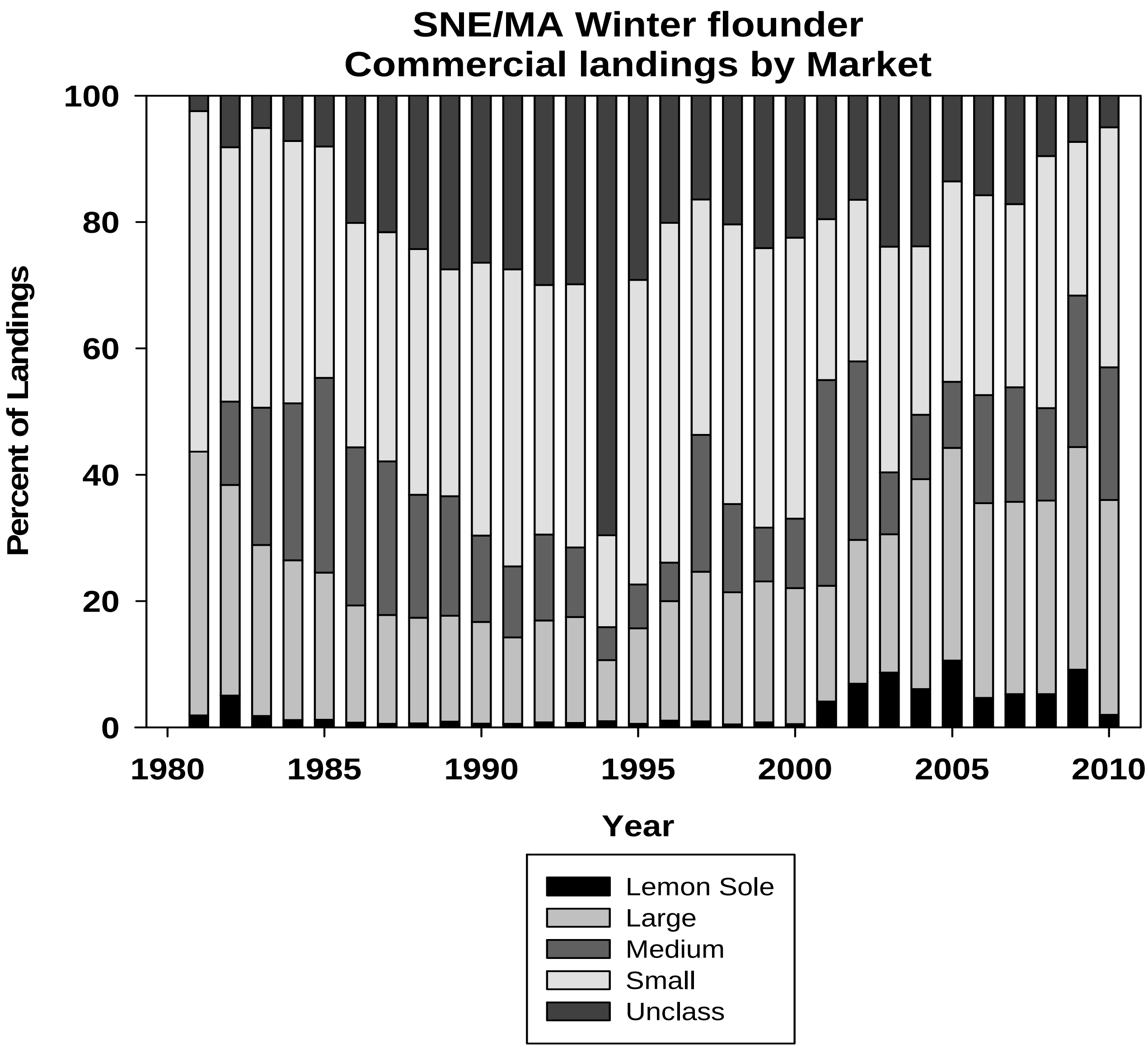


Figure A16. Commercial fishery landings of SNE/MA winter flounder by market category.

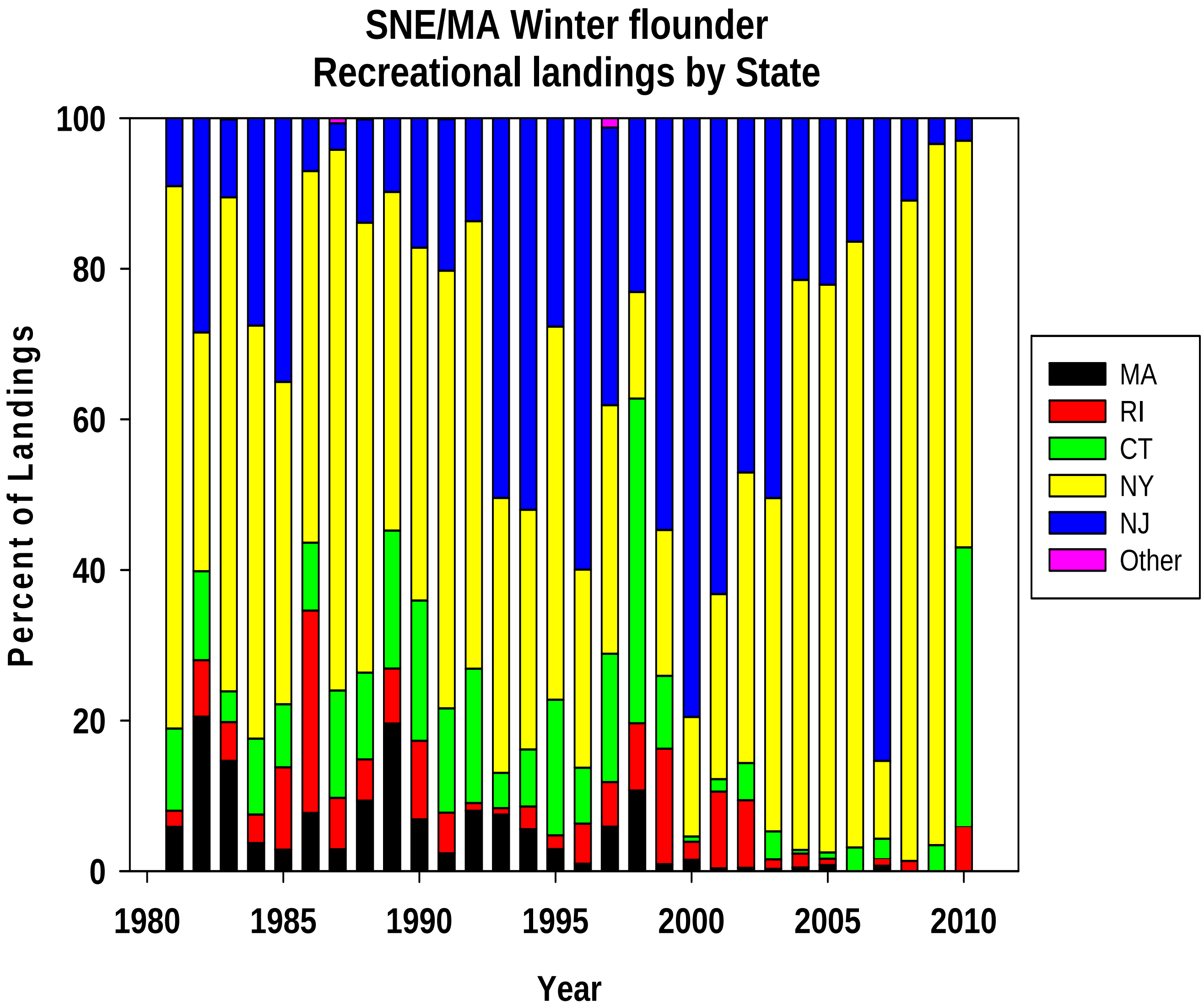


Figure A17. Recreational fishery landings of SNE/MA winter flounder by state.

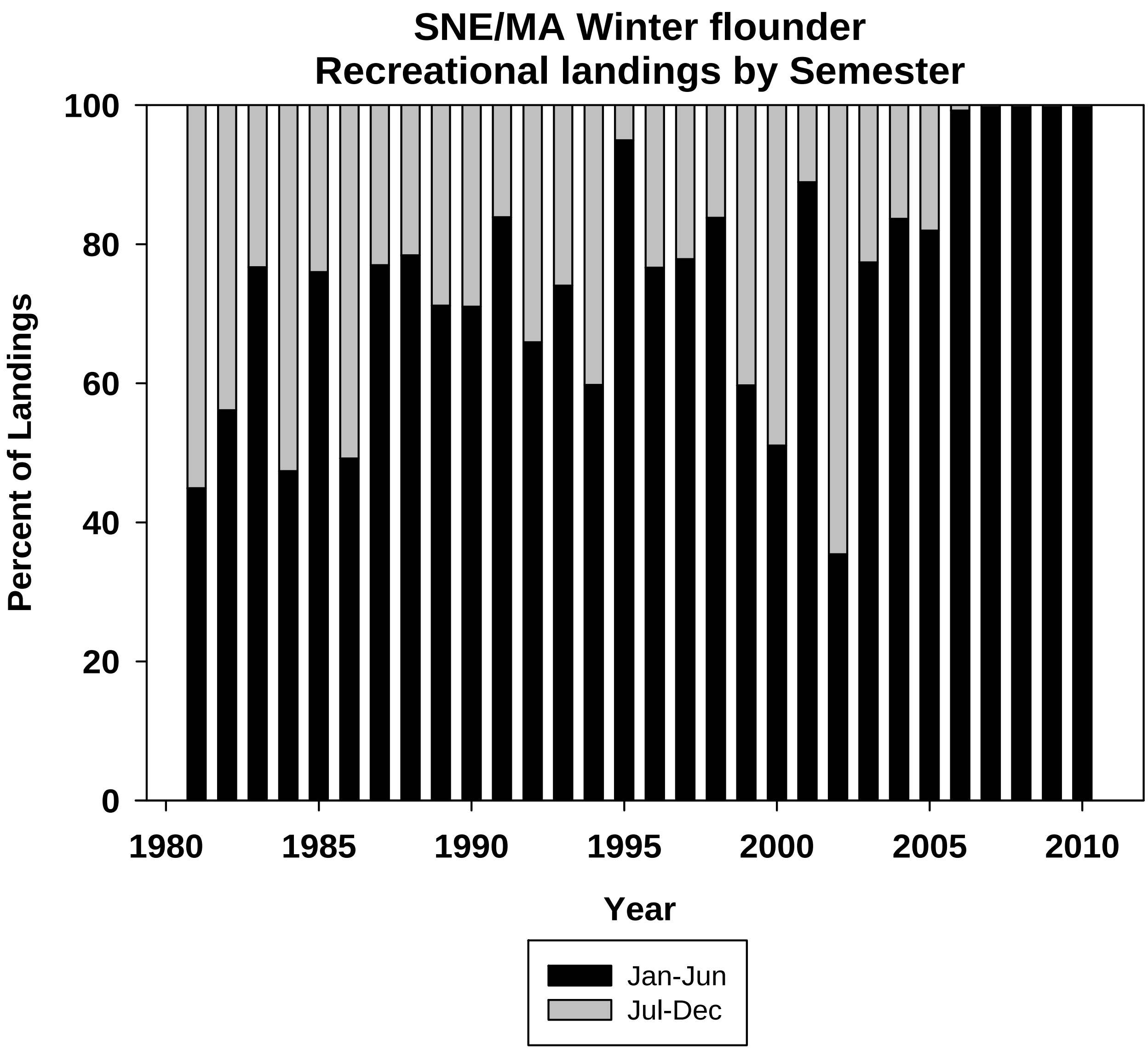


Figure A18. Recreational fishery landings of SNE/MA winter flounder by semester (half-year period).

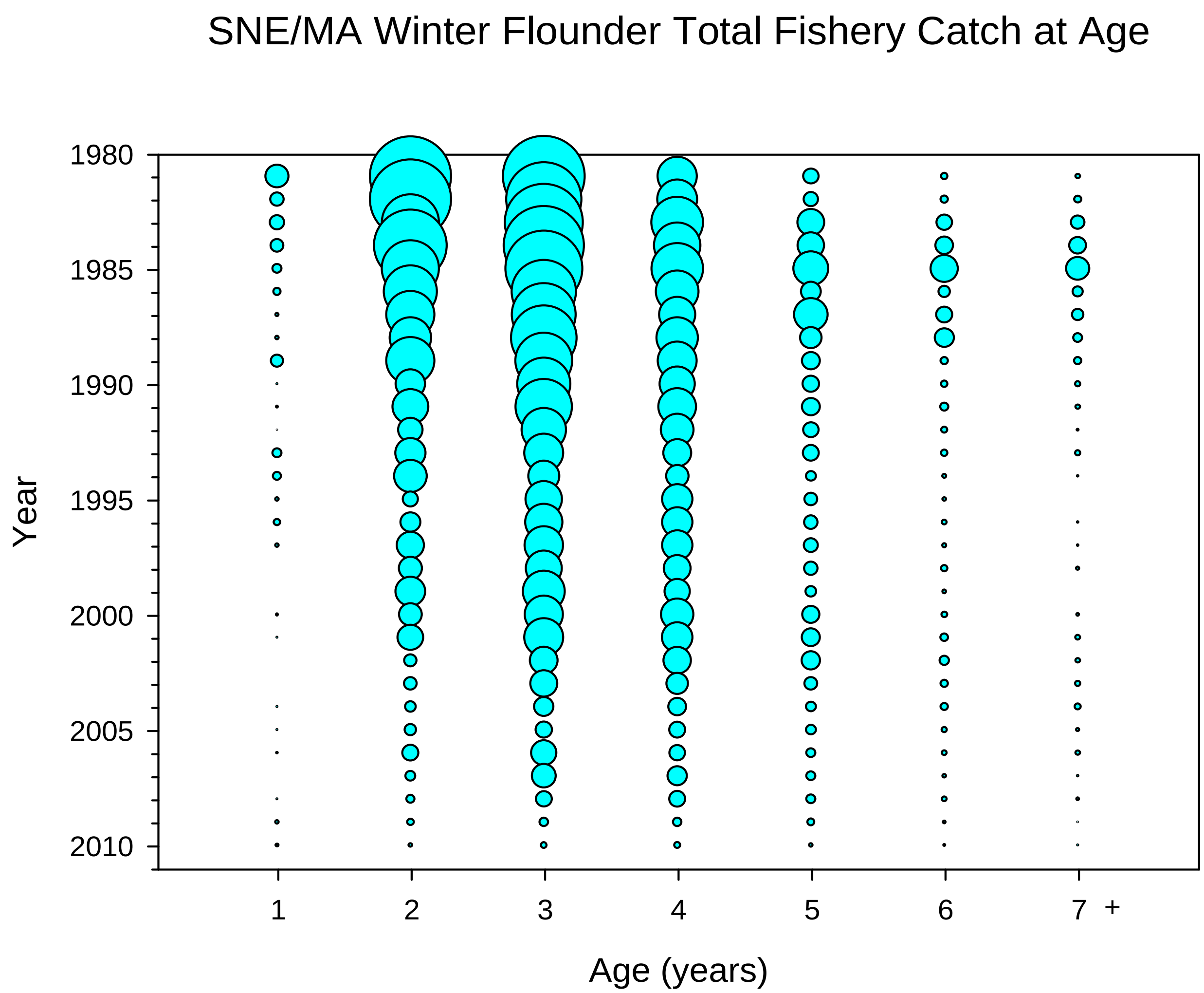


Figure A19. Age structure of the SNE/MA winter flounder catch.

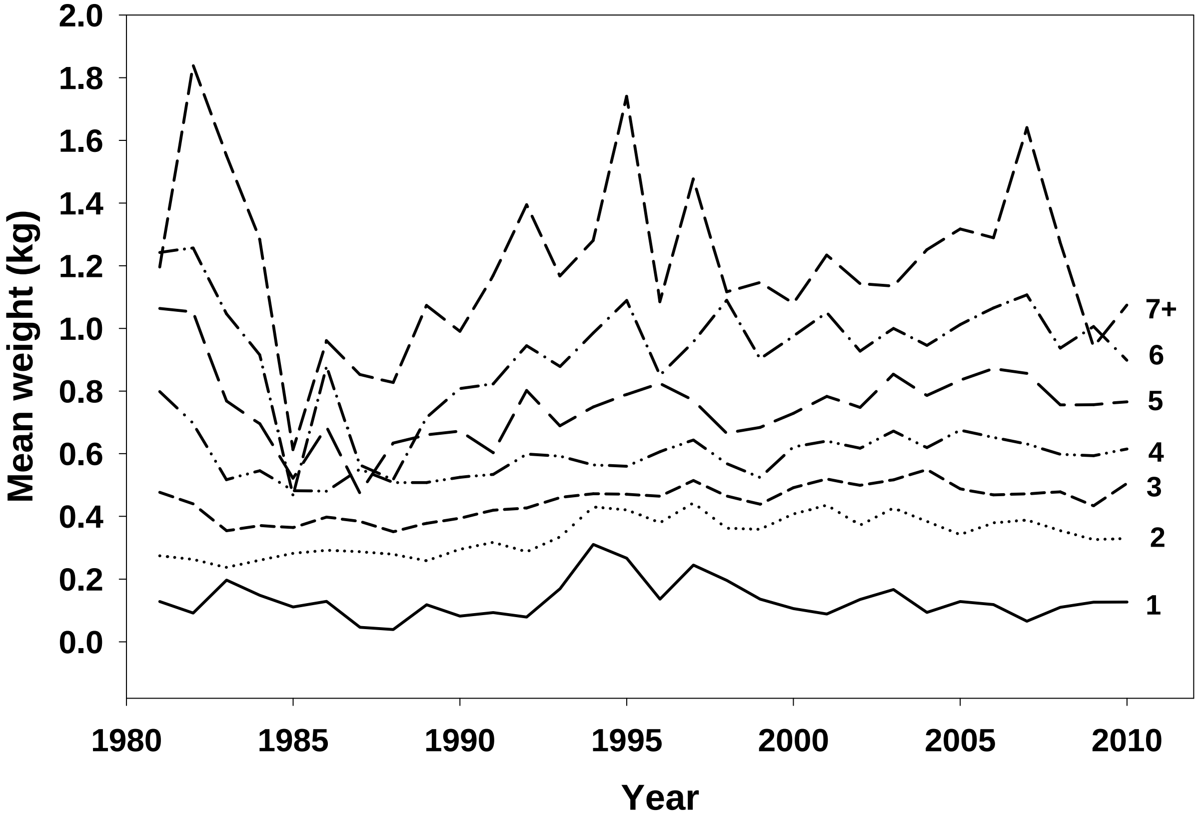


Figure A20. Trends in mean weight at age in the total catch of SNE/MA winter flounder.

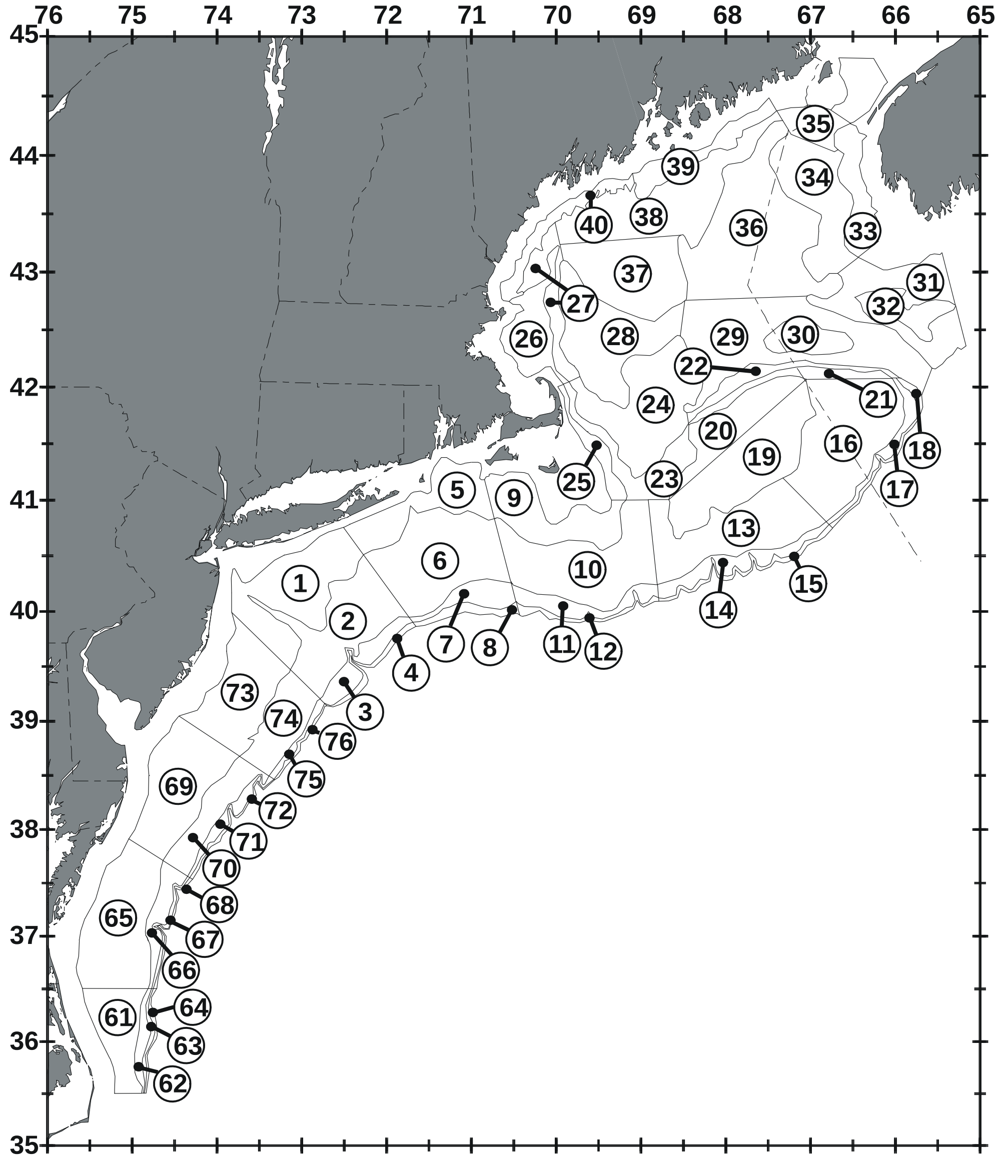


Figure A21. Offshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys.

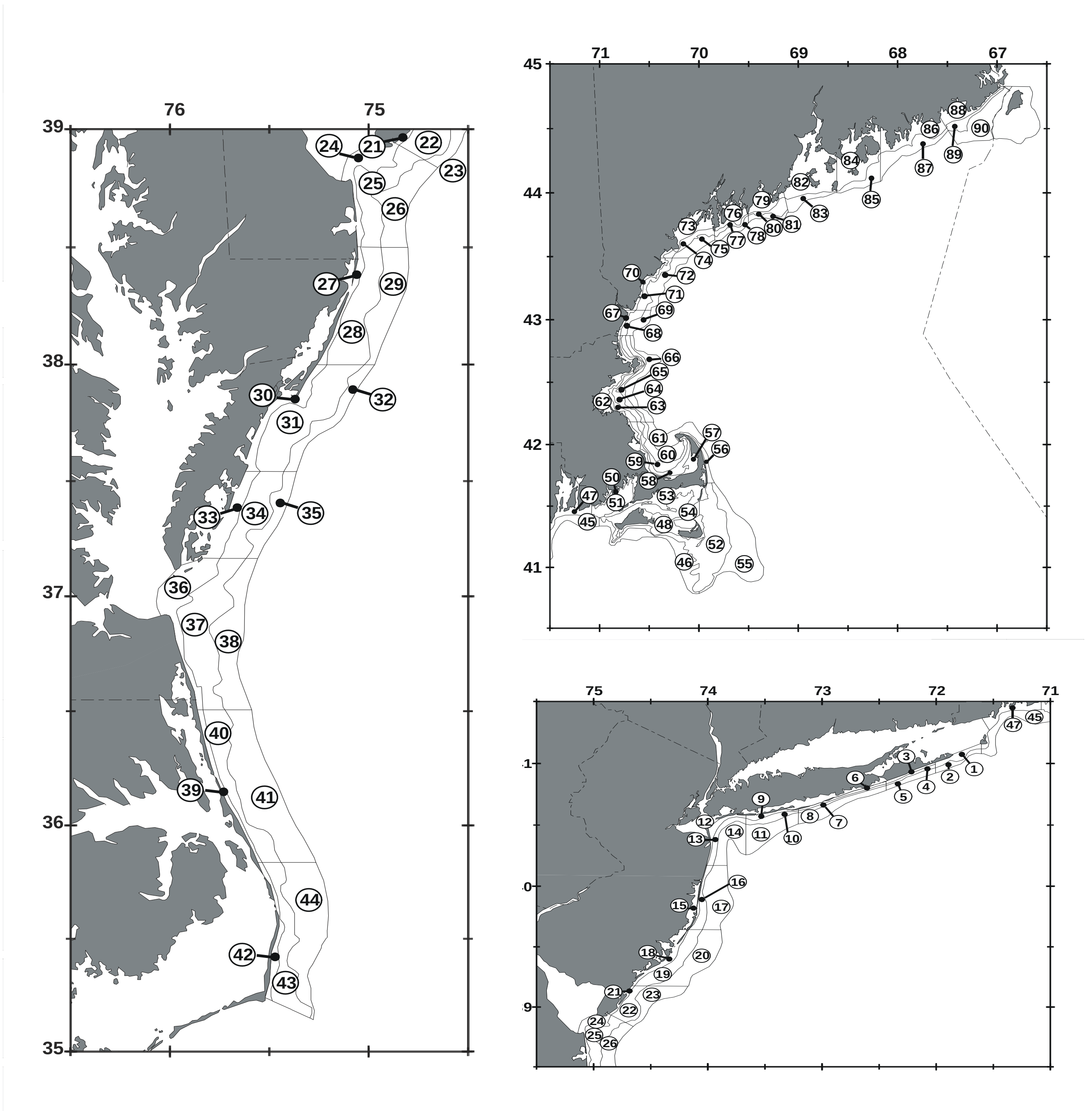


Figure A22. Inshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys.

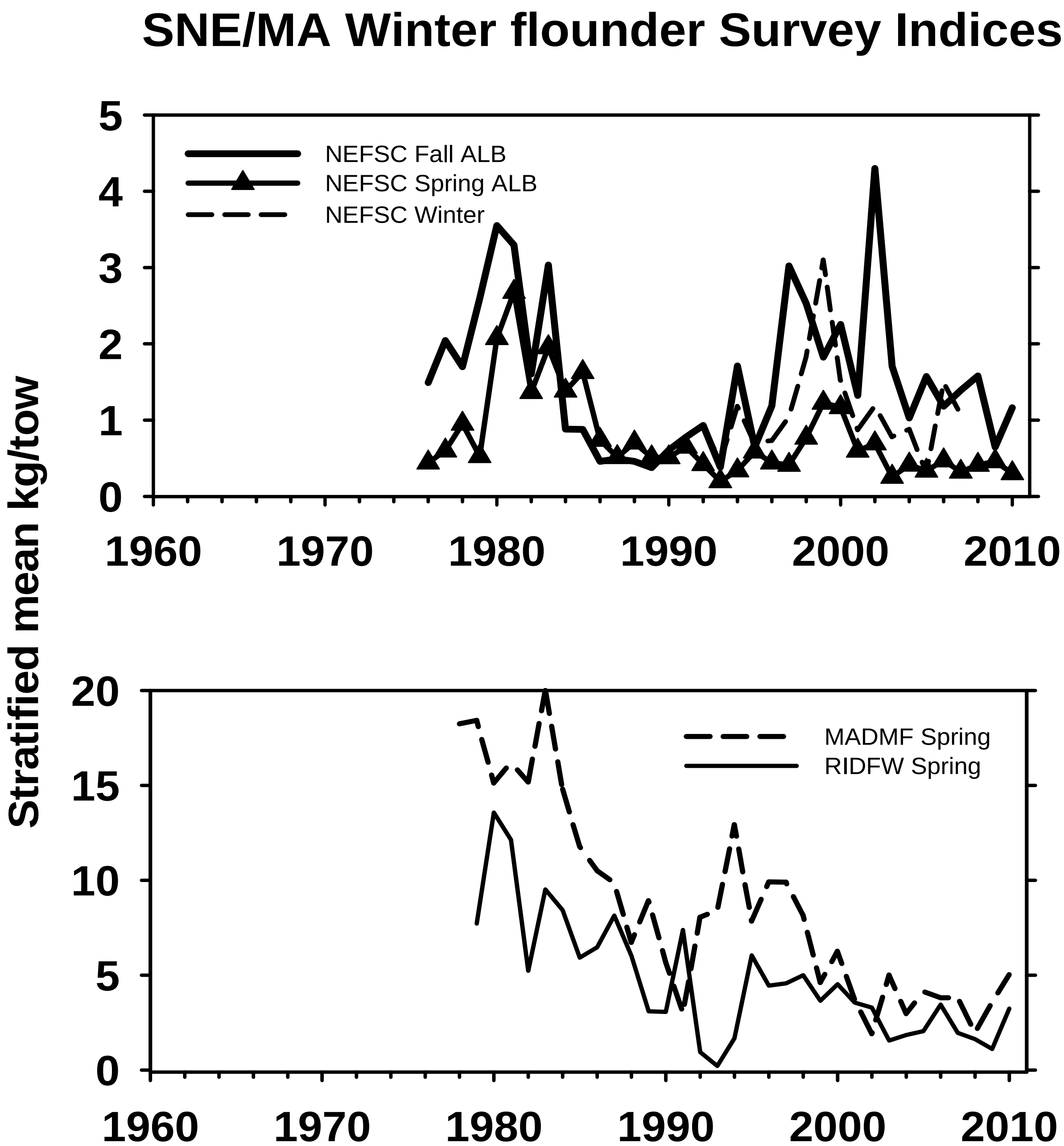


Figure A23. Trends in research survey indices for SNE/MA winter flounder.

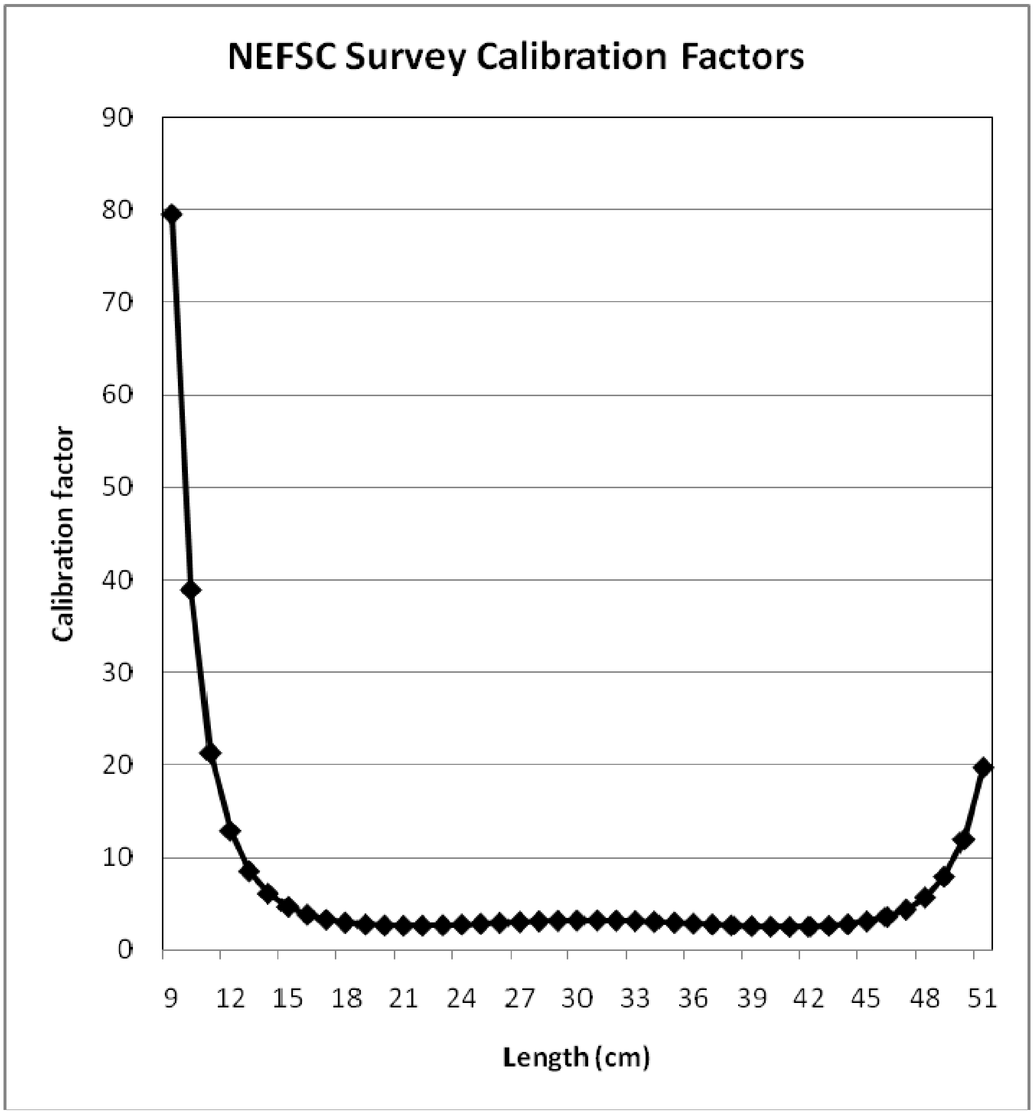


Figure A24. NEFSC trawl survey calibration factors at length for SNE/MA winter flounder.

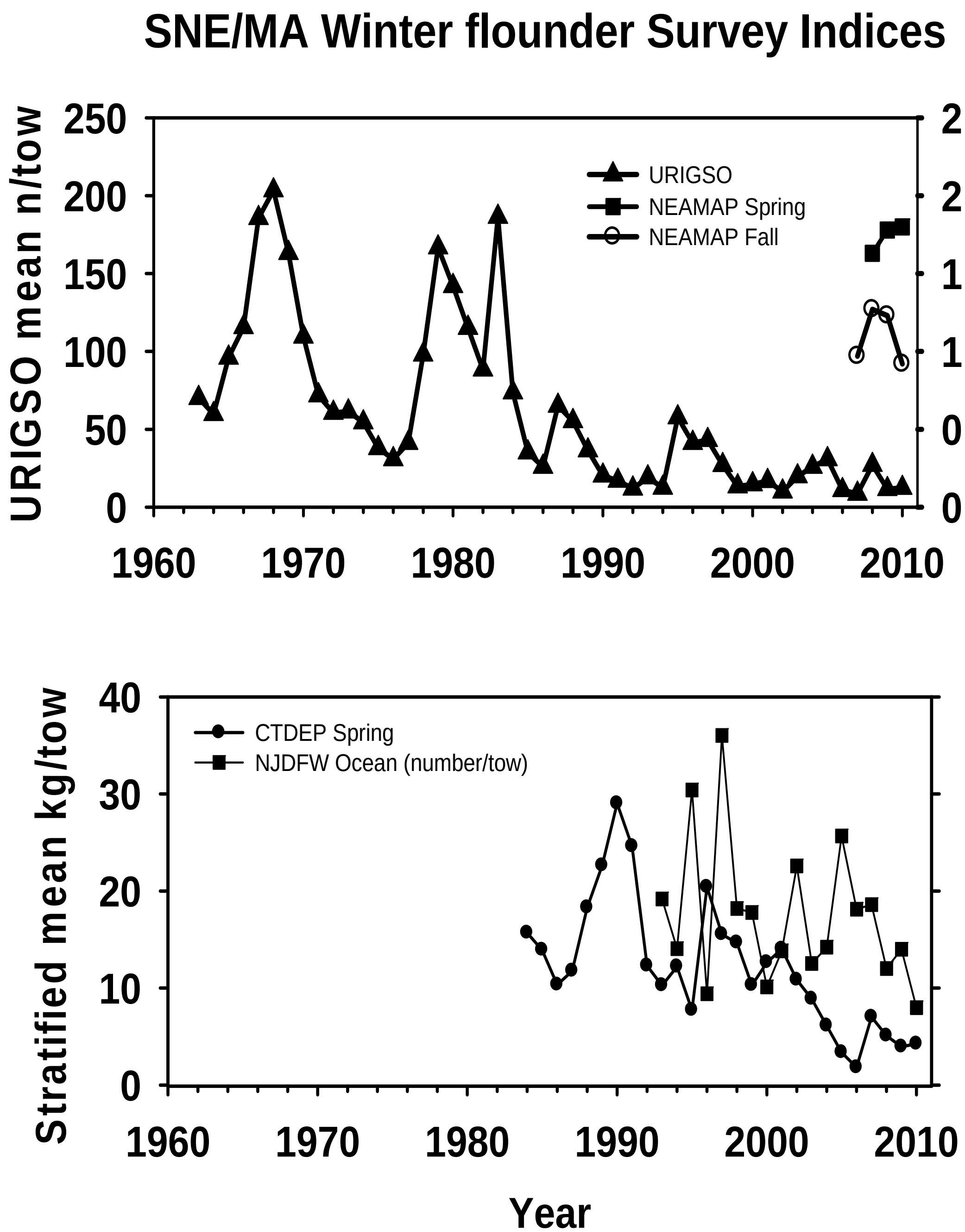


Figure A25. Trends in research survey indices for SNE/MA winter flounder.

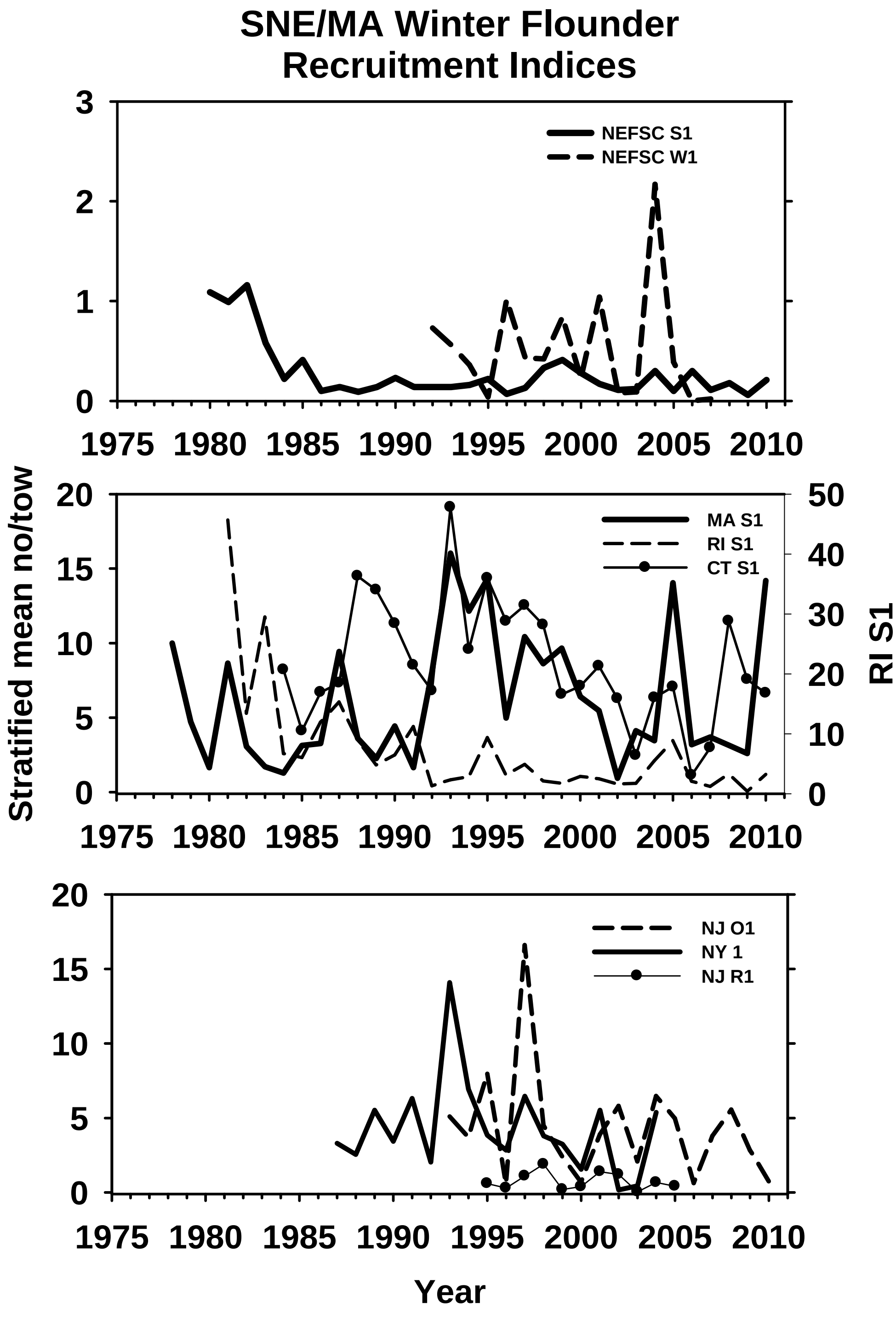


Figure A26. Trends in research survey recruitment indices for SNE/MA winter flounder.

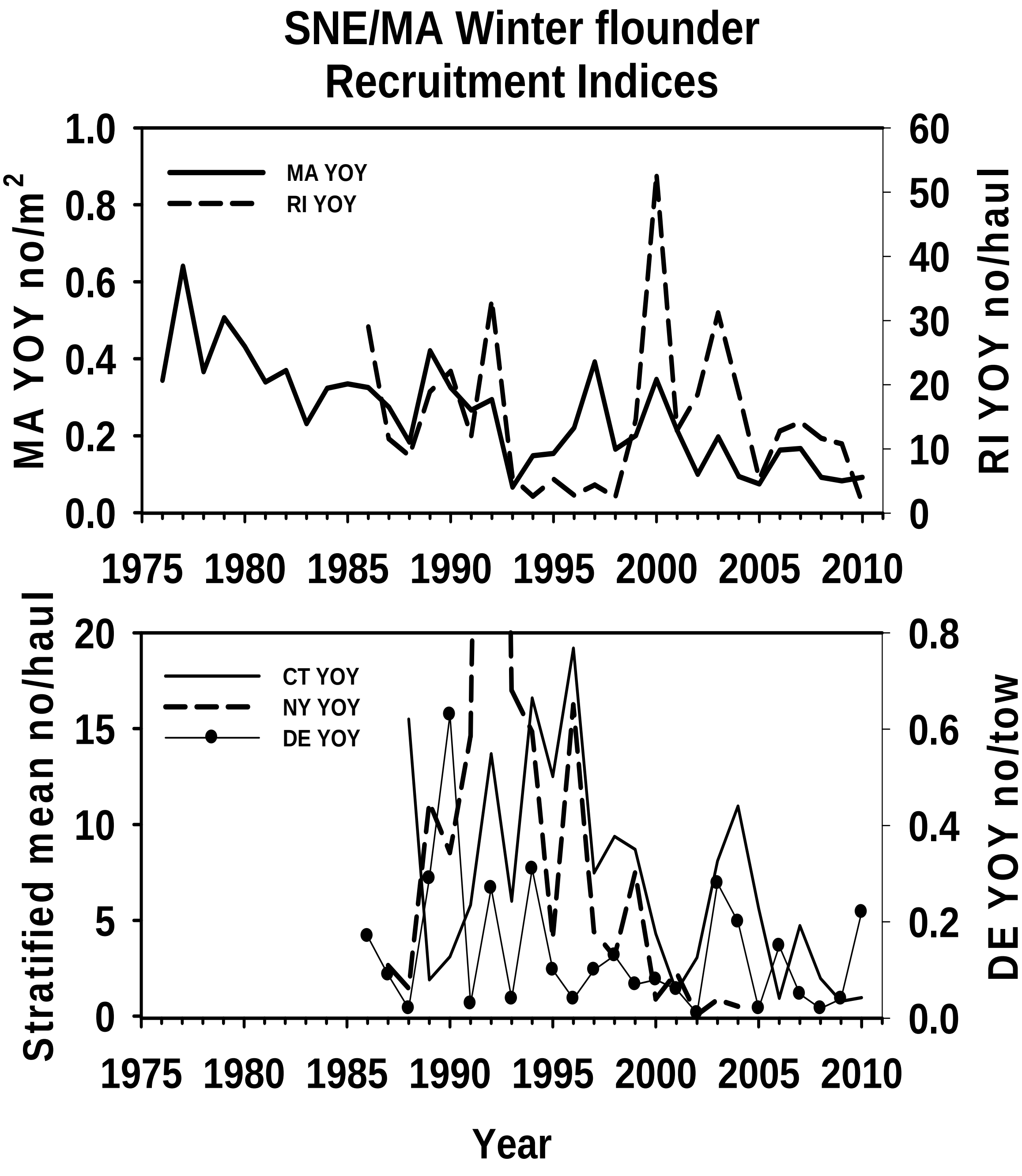


Figure A27. Trends in research survey recruitment indices for SNE/MA winter flounder.

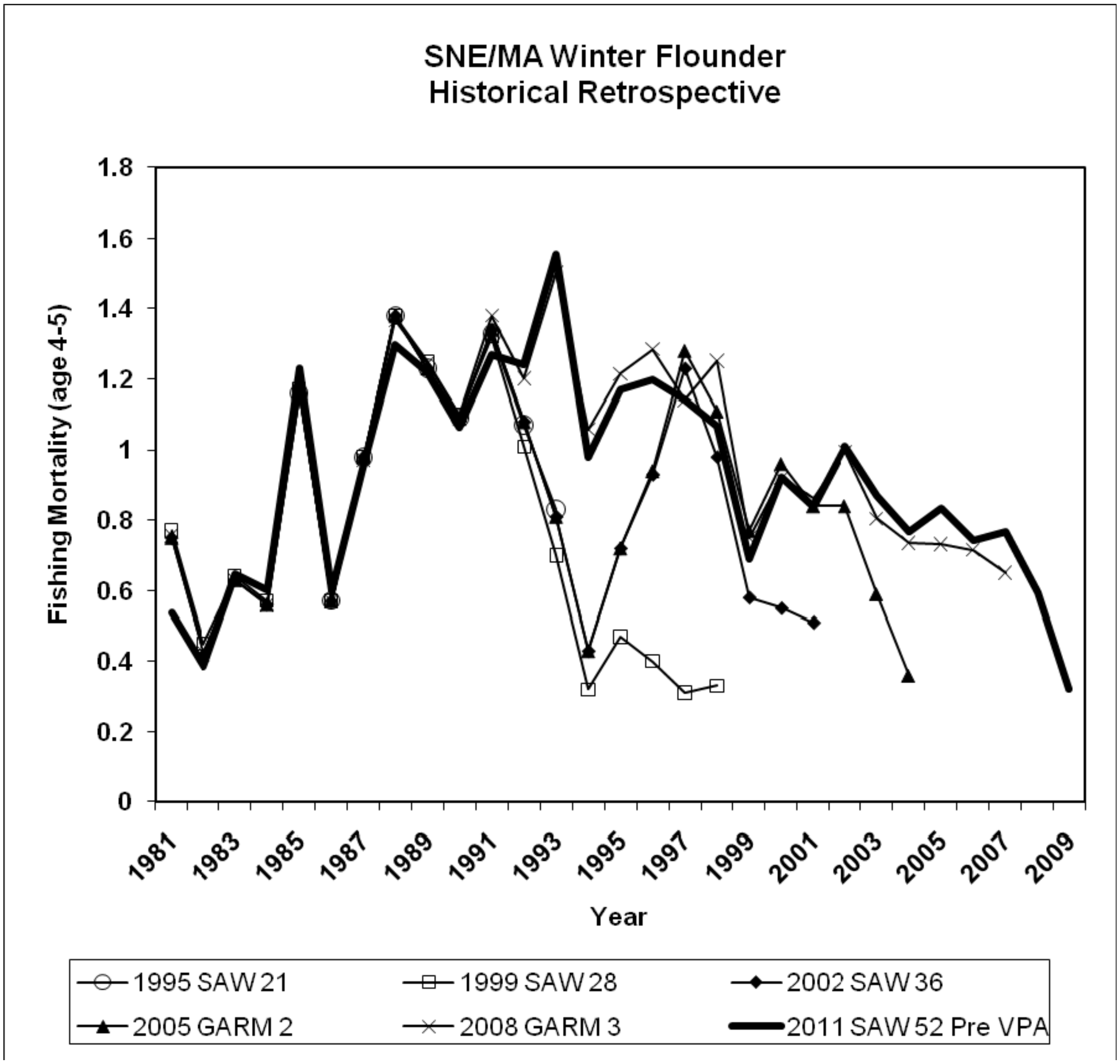


Figure A28. Comparison of estimates of Fishing Mortality (age 4-5) from previous SNE/MA stock assessments with estimates from a Preliminary ADAPT VPA model with M = 0.2.

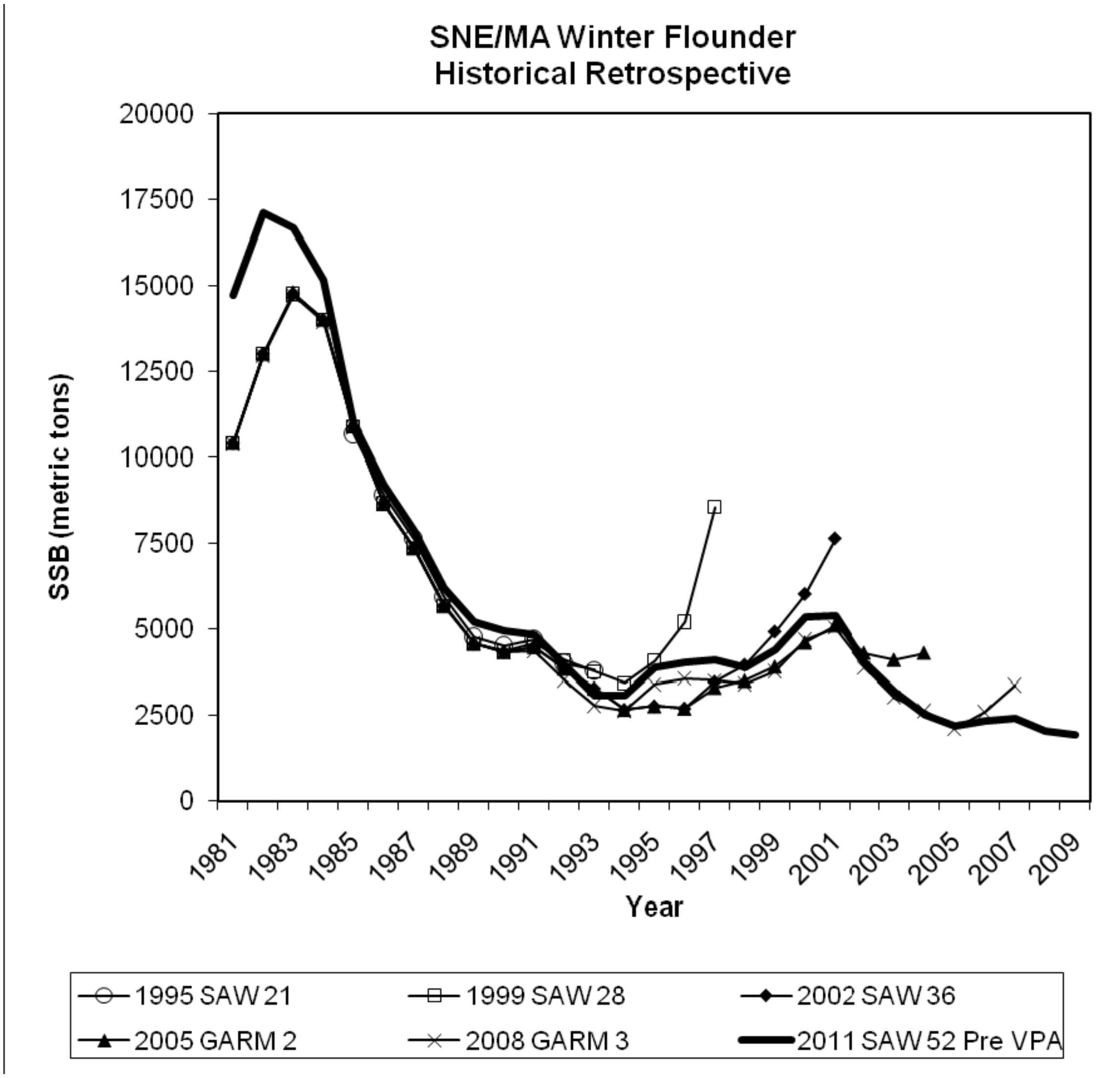


Figure A29. Comparison of estimates of Spawning Stock Biomass (SSB; metric tons) from previous SNE/MA stock assessments with estimates from a Preliminary ADAPT VPA model with M = 0.2.

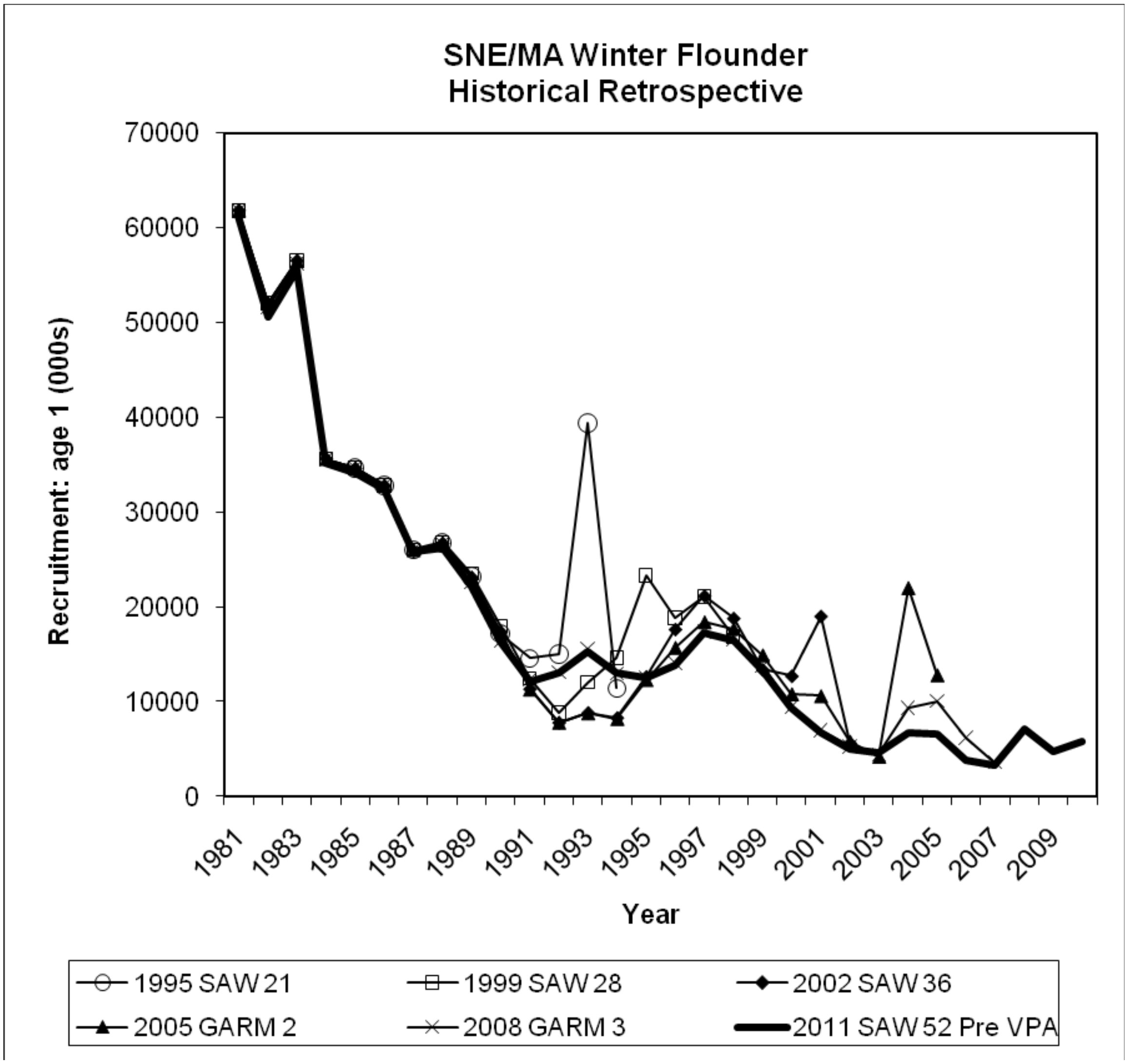


Figure A30. Comparison of estimates of Recruitment at age 1 (000s) from previous SNE/MA stock assessments with estimates from a Preliminary ADAPT VPA model with M = 0.2.

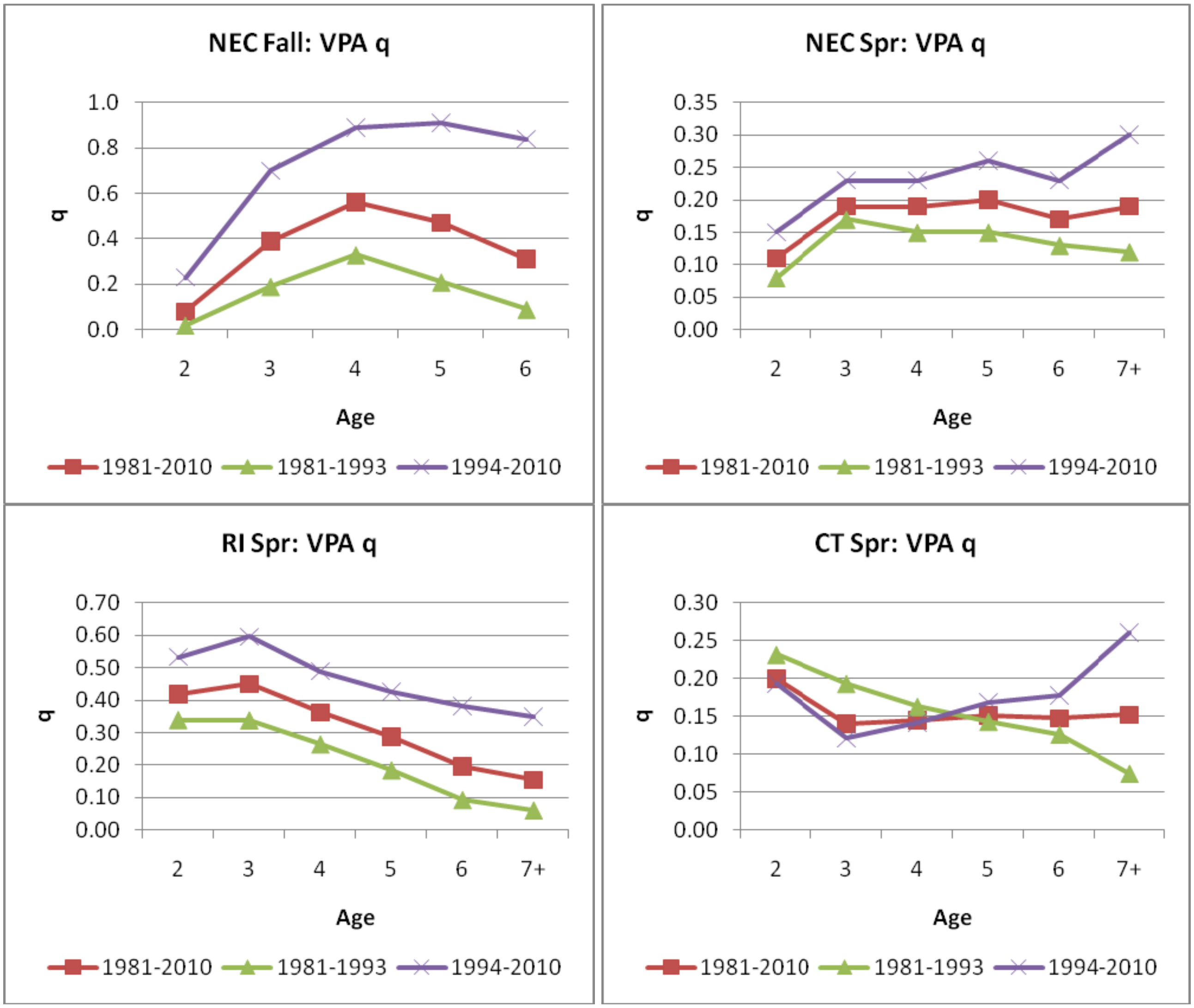


Figure A31. Patterns in survey catchability at age (*q*) from Preliminary SNE/MA winter flounder ADAPT BASE (1981-2010) and SPLIT (1981-1993; 1994-2010) model runs with M = 0.2.

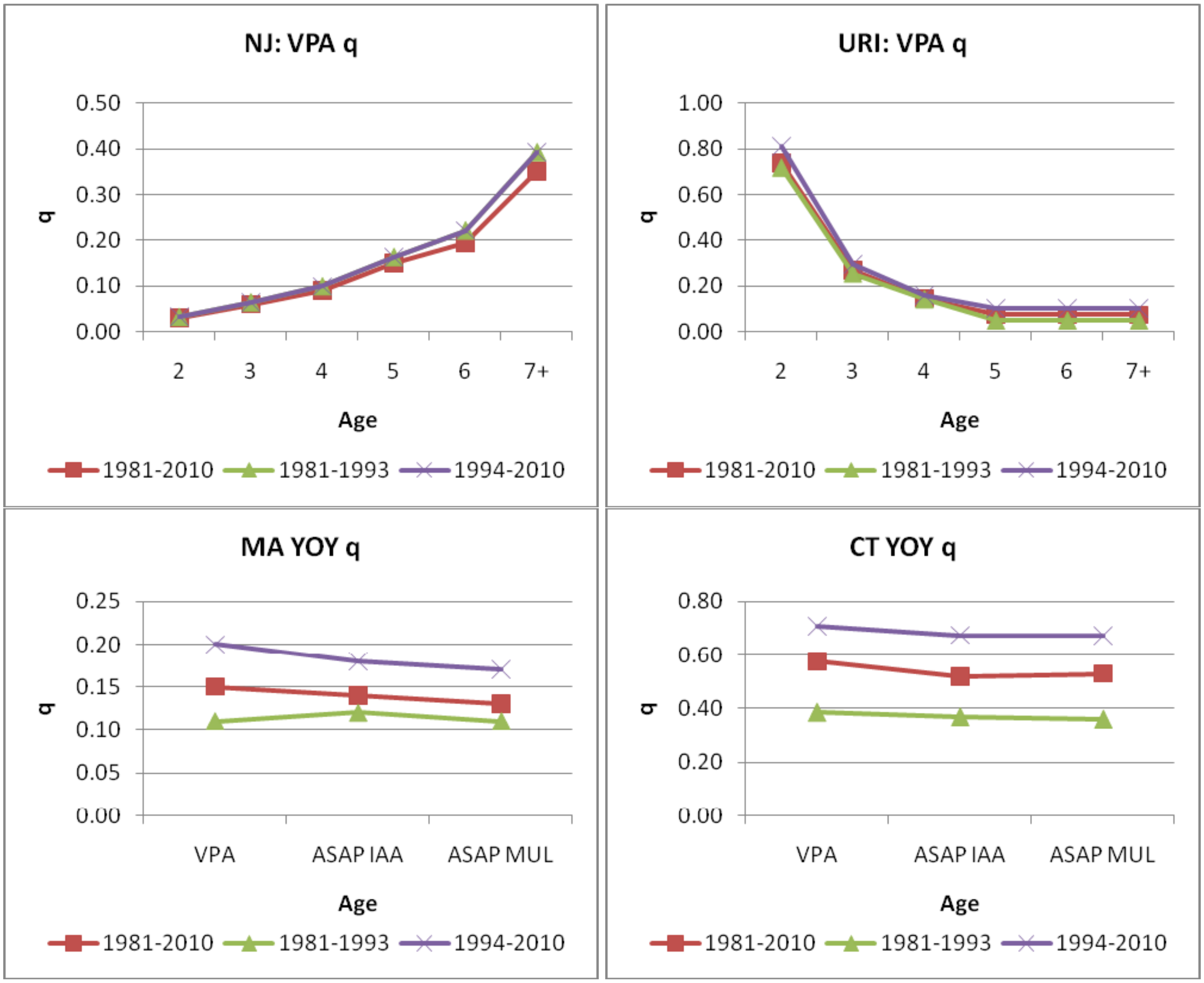


Figure A32. Patterns in survey catchability at age (*q*) from Preliminary SNE/MA winter flounder ADAPT BASE (1981-2010) and SPLIT (1981-1993; 1994-2010) model runs with M = 0.2.

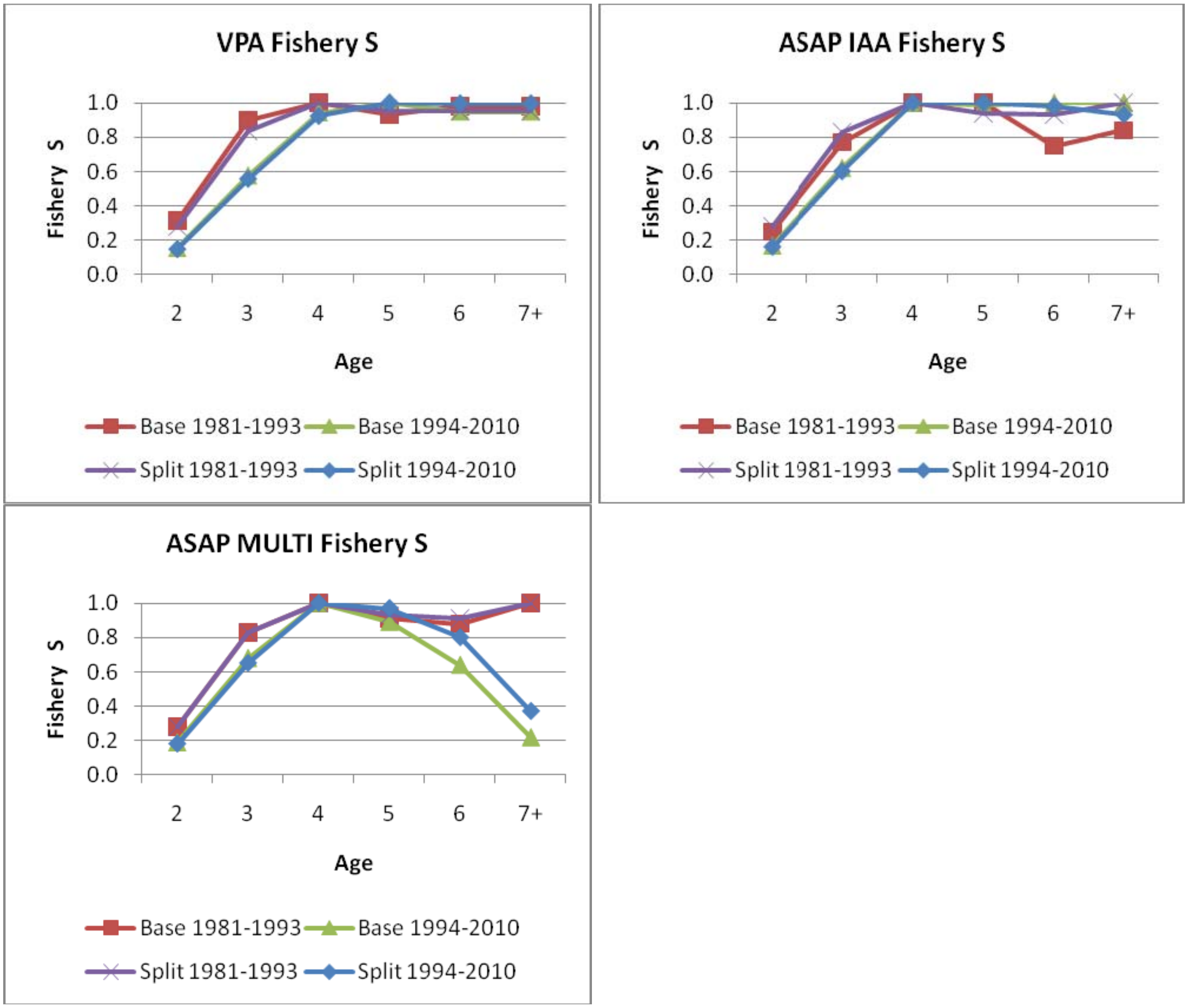


Figure A33. Patterns in fishery selectivity from Preliminary SNE/MA winter flounder ADAPT VPA, ASAP IAA, and ASAP MULTI model runs with M = 0.2.

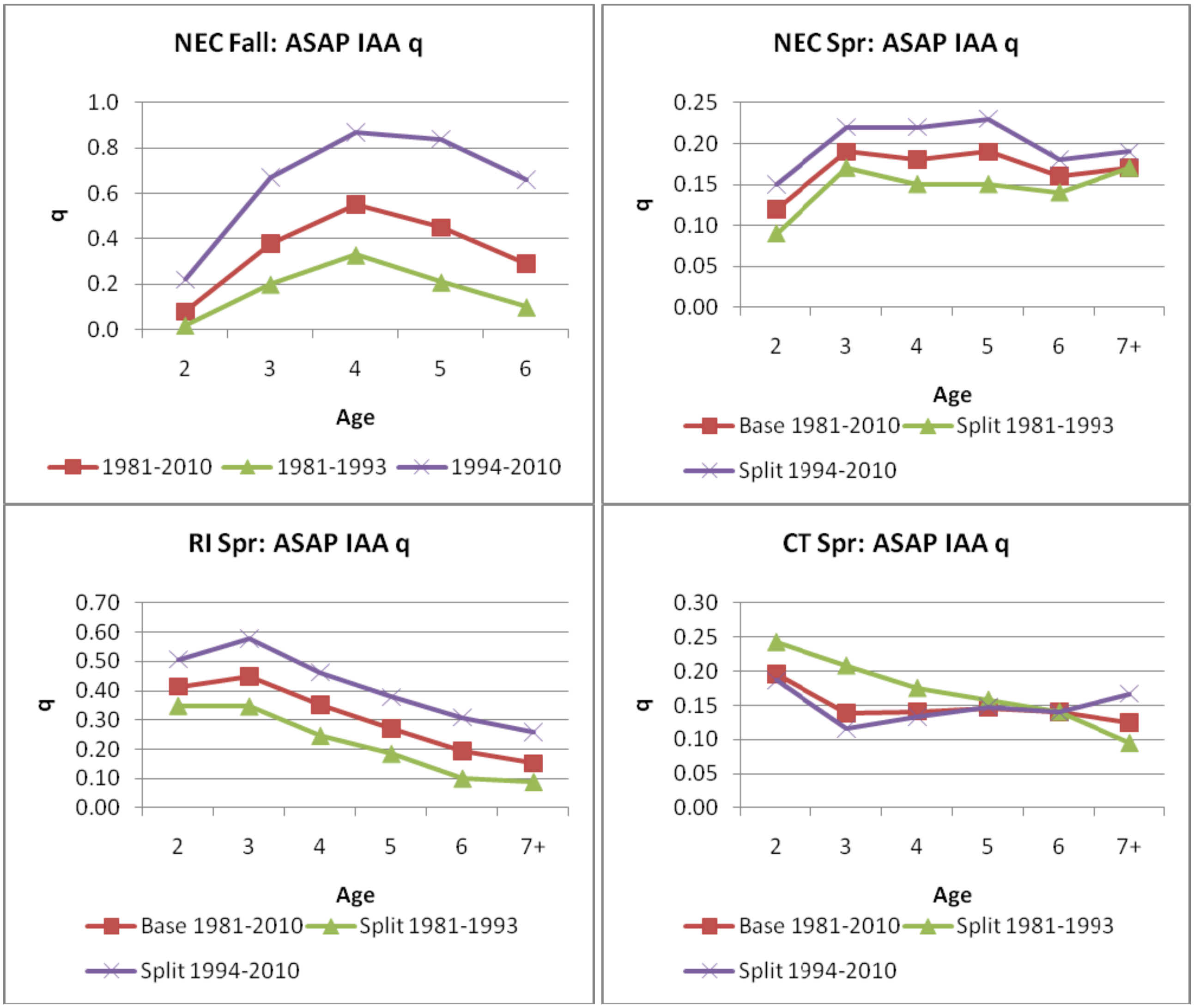


Figure A34. Patterns in survey catchability at age (*q*) from Preliminary SNE/MA winter flounder ASAP IAA BASE and SPLIT model runs with M = 0.2.

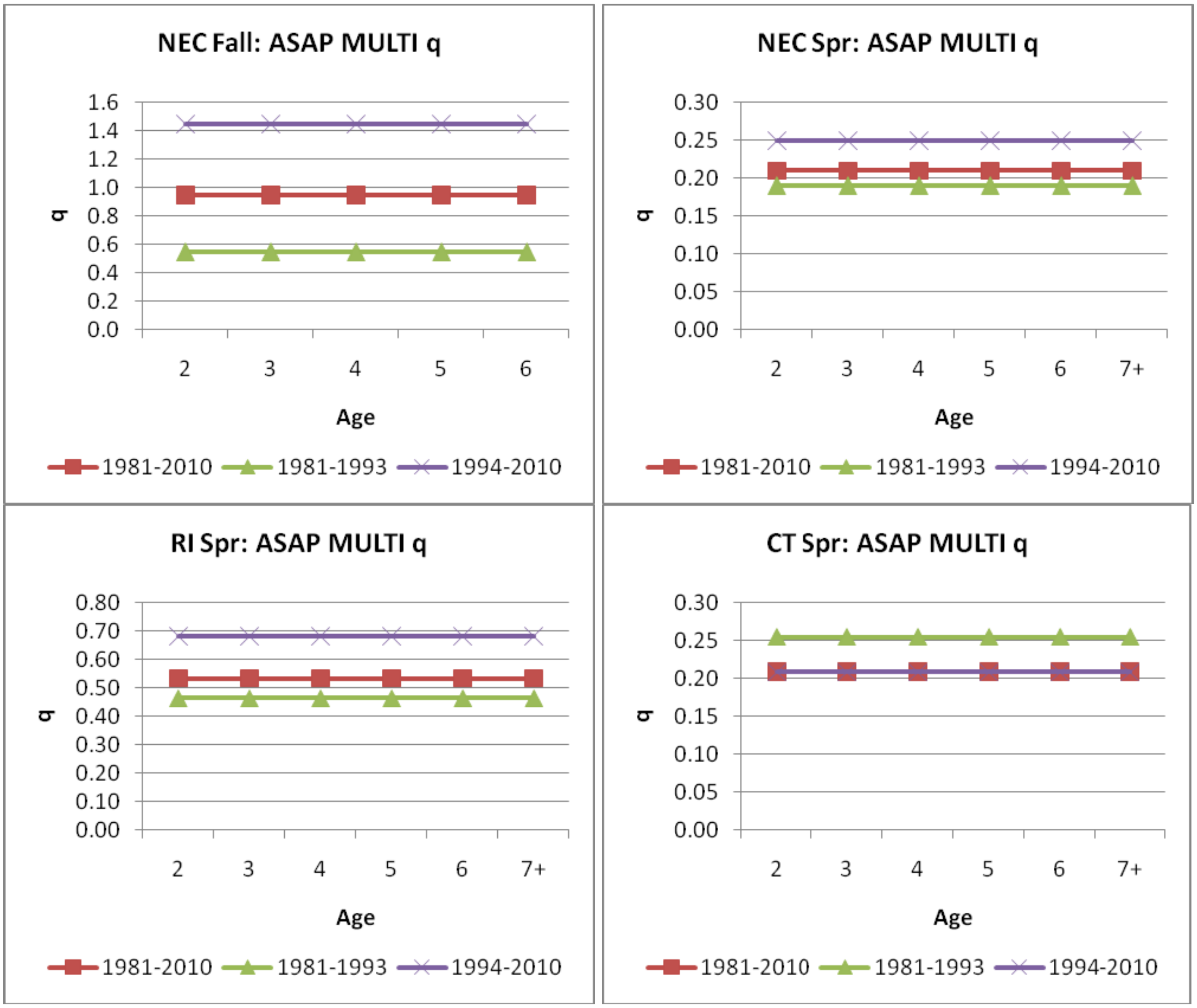


Figure A35. Patterns in aggregate survey catchability (q) from Preliminary SNE/MA winter flounder ASAP MULTI BASE and SPLIT model runs with M = 0.2.

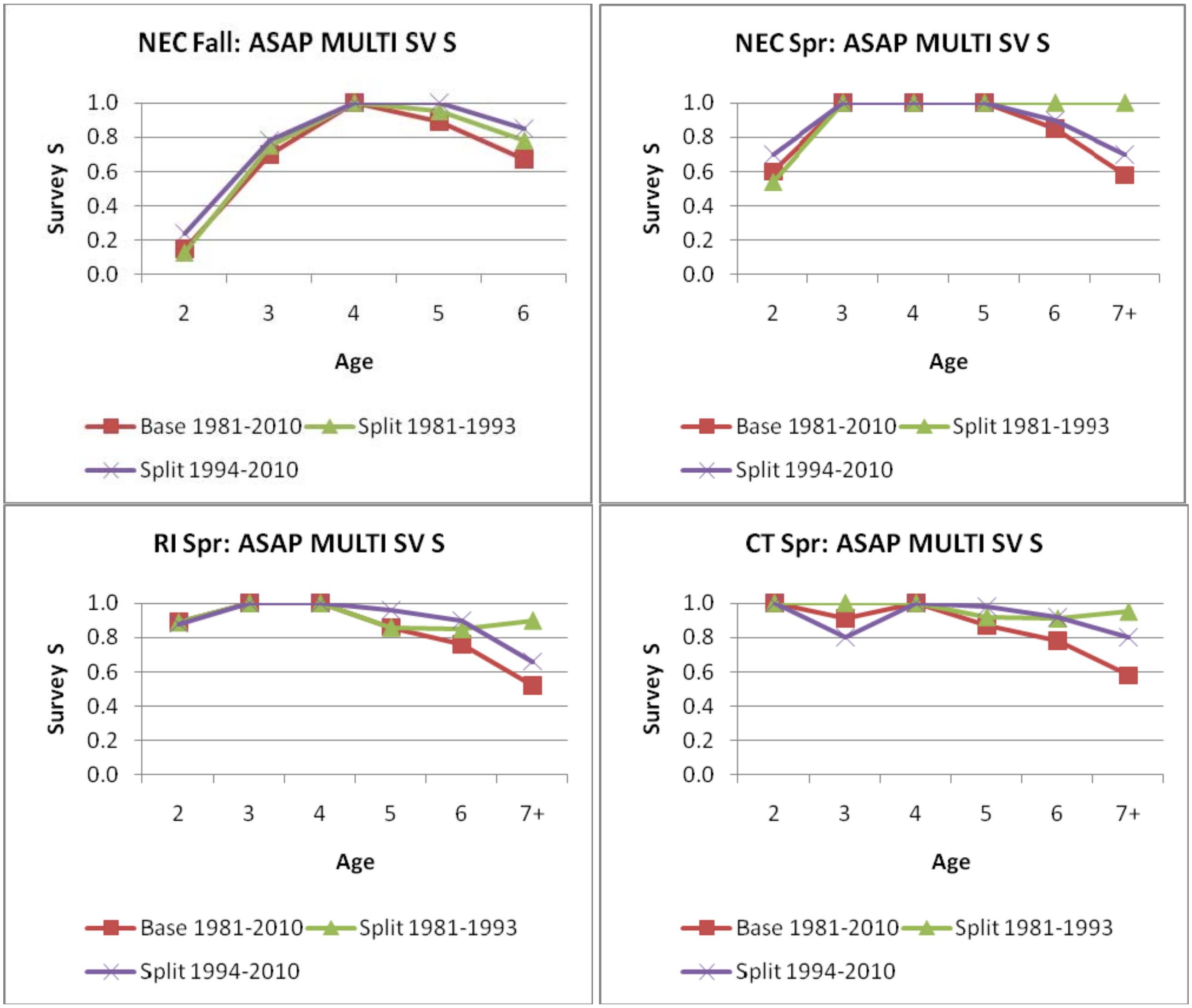


Figure A36. Patterns in survey selectivity from Preliminary SNE/MA winter flounder ASAP MULTI BASE and SPLIT model runs with M = 0.2.

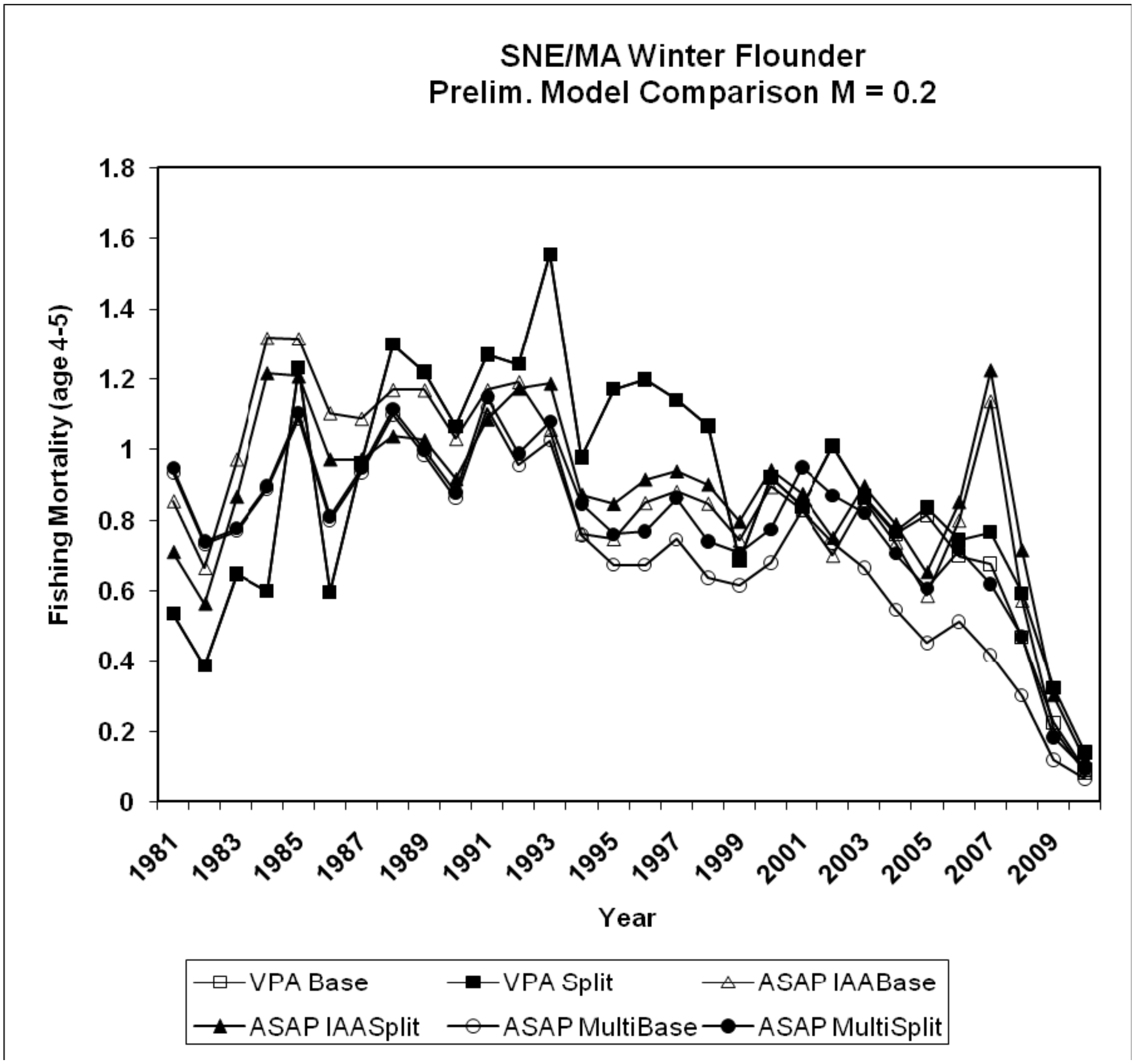


Figure A37. Estimates of Fishing Mortality (age 4-5) from Preliminary VPA and ASAP models with M = 0.2.

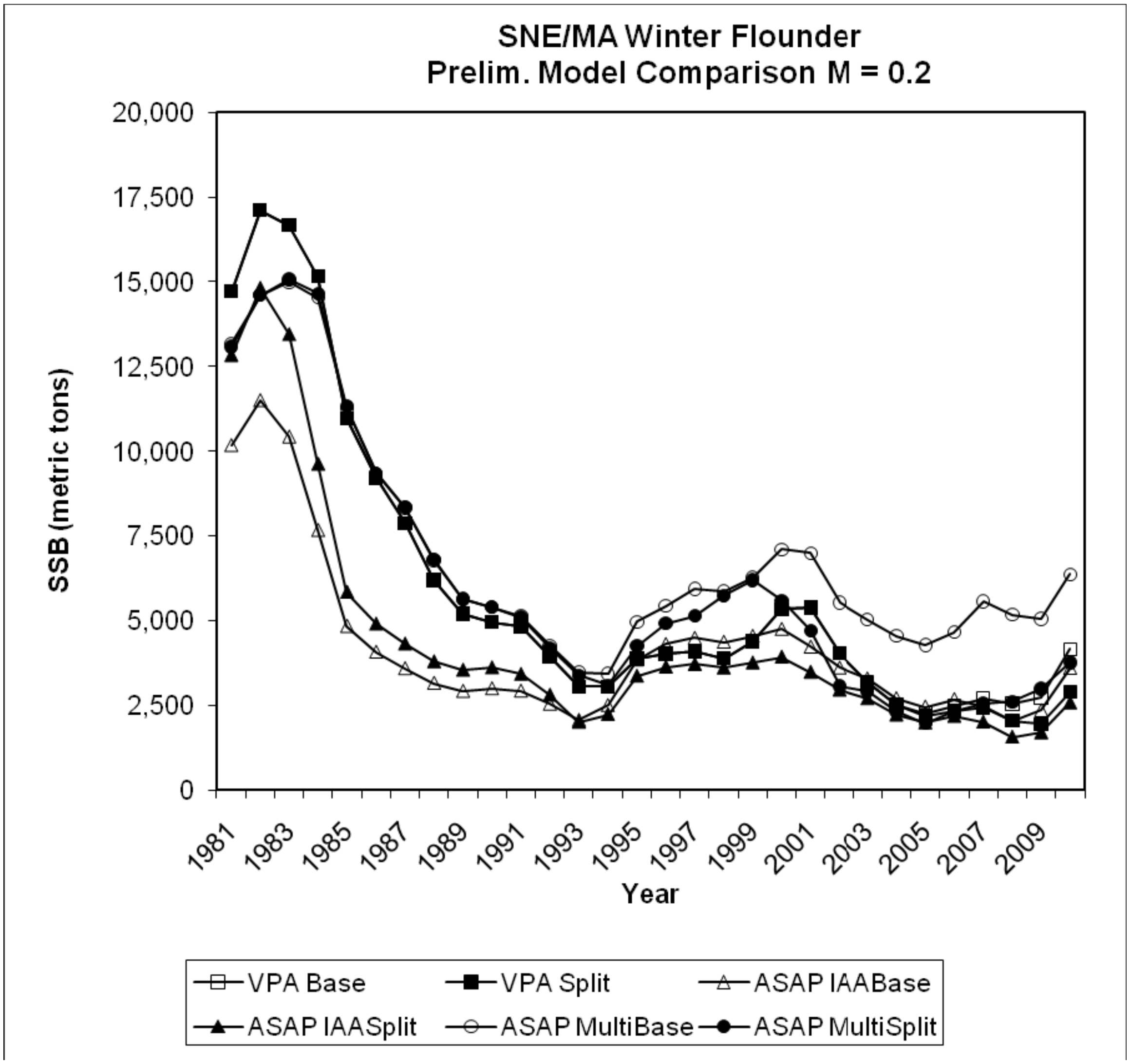


Figure A38. Estimates of Spawning Stock Biomass (SSB) from Preliminary VPA and ASAP models with M = 0.2.

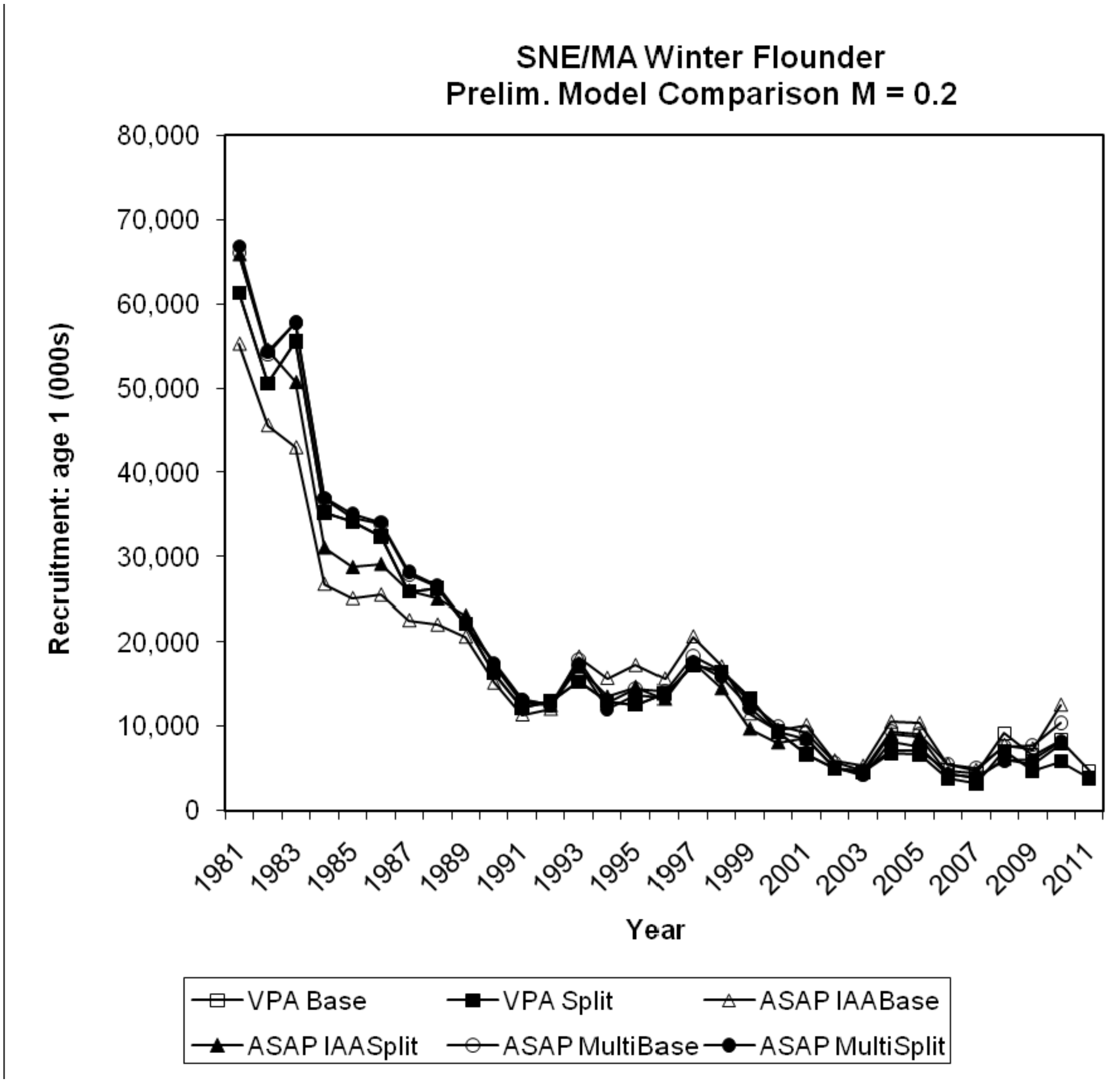


Figure A39. Estimates of Recruitment at age 1 (000s) from Preliminary VPA and ASAP models with M = 0.2.

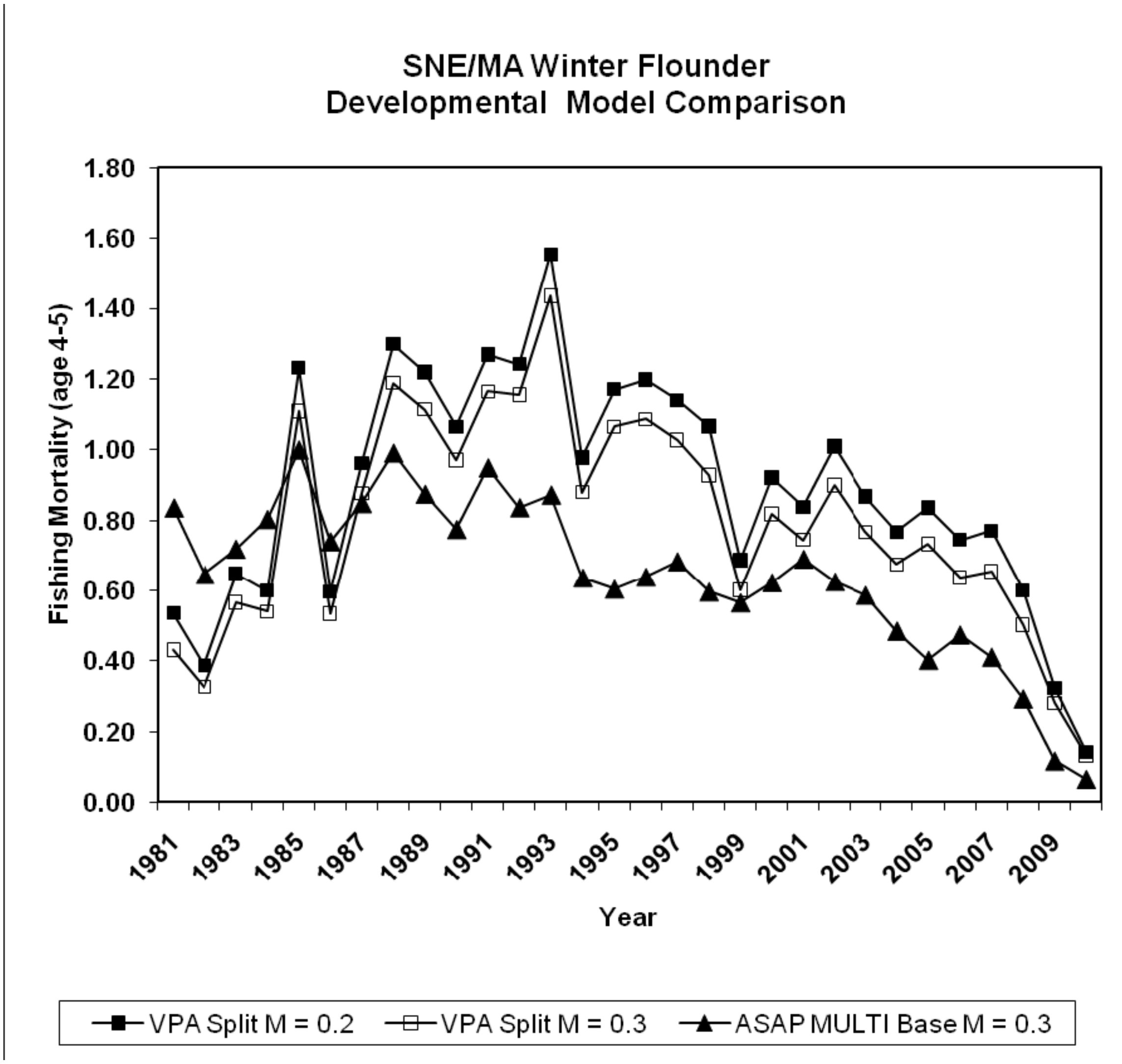


Figure A40. Estimates of Fishing Mortality (age 4-5) from Developmental VPA and ASAP models.

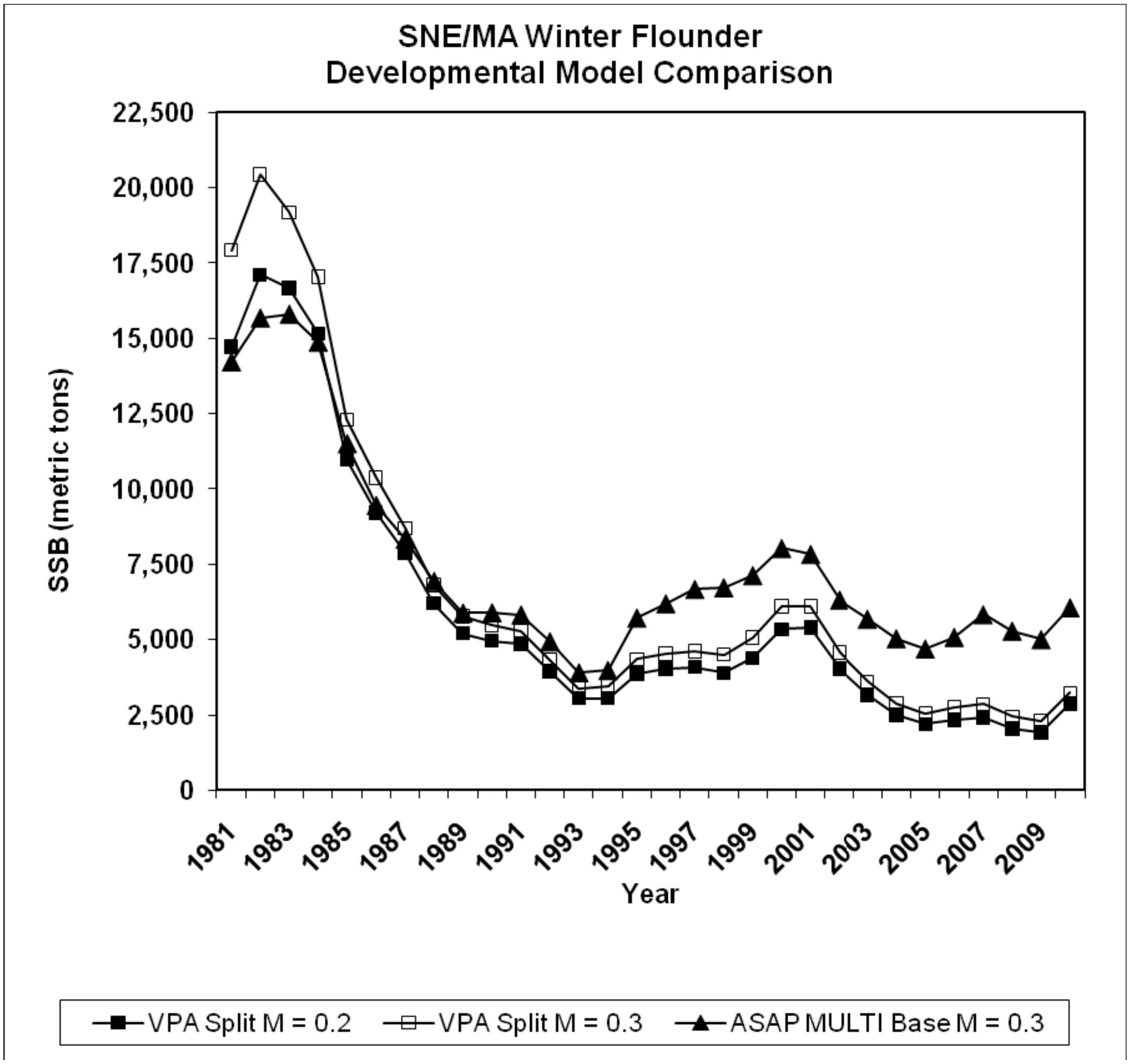


Figure A41. Estimates of Spawning Stock Biomass (SSB) from Developmental VPA and ASAP models.

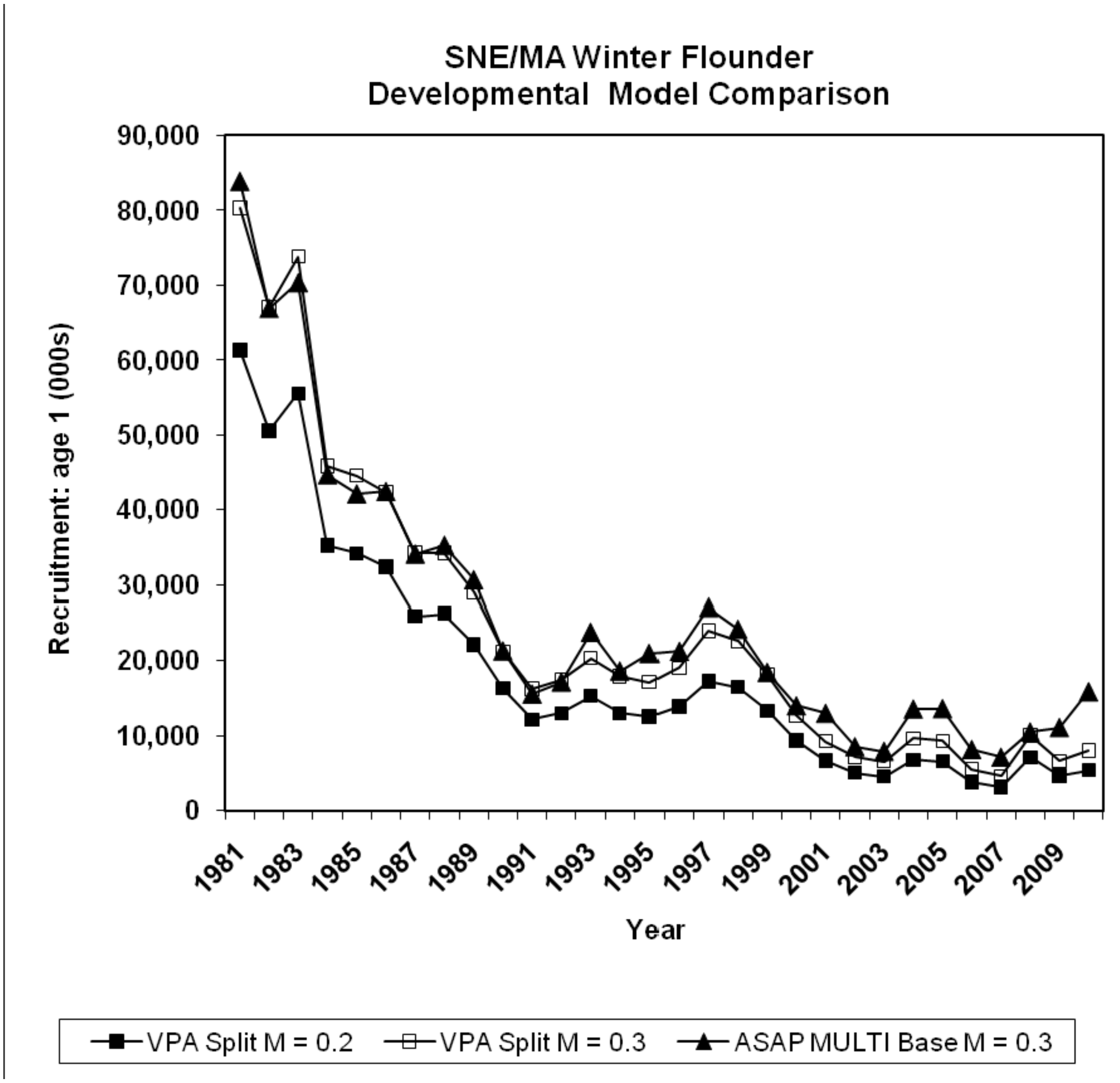
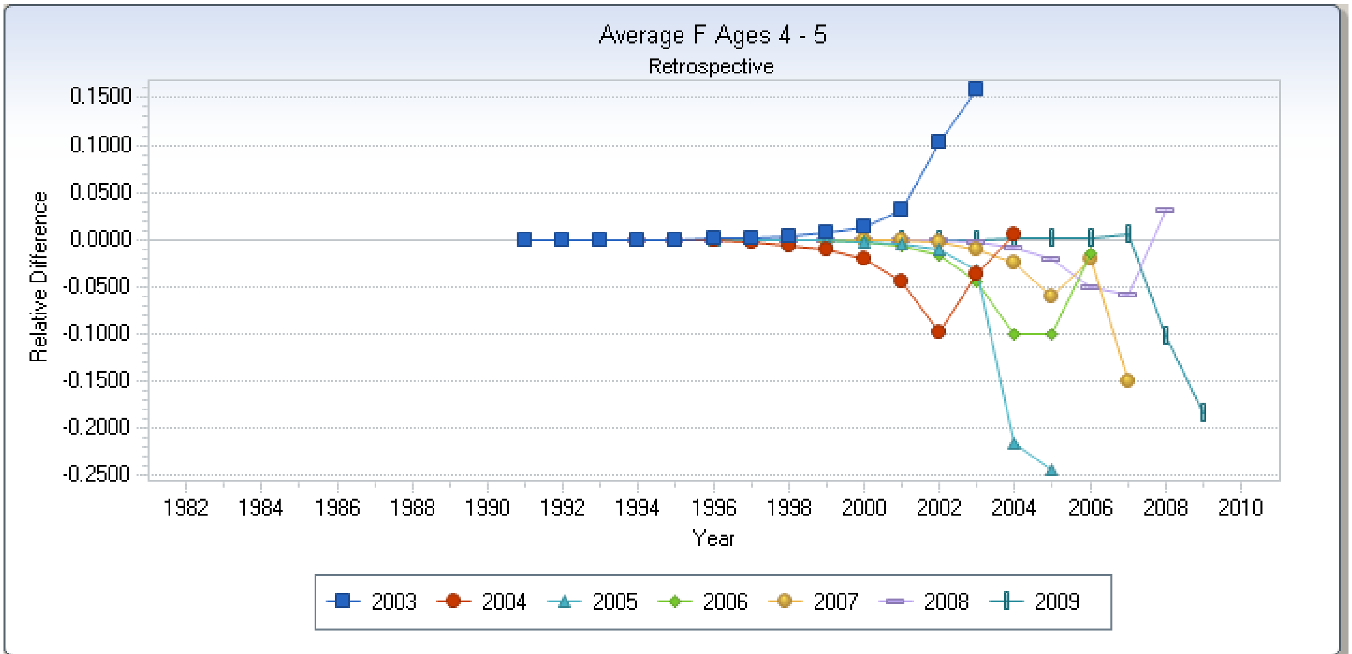


Figure A42. Estimates of Recruitment at age 1 (000s) from Developmental VPA and ASAP models.



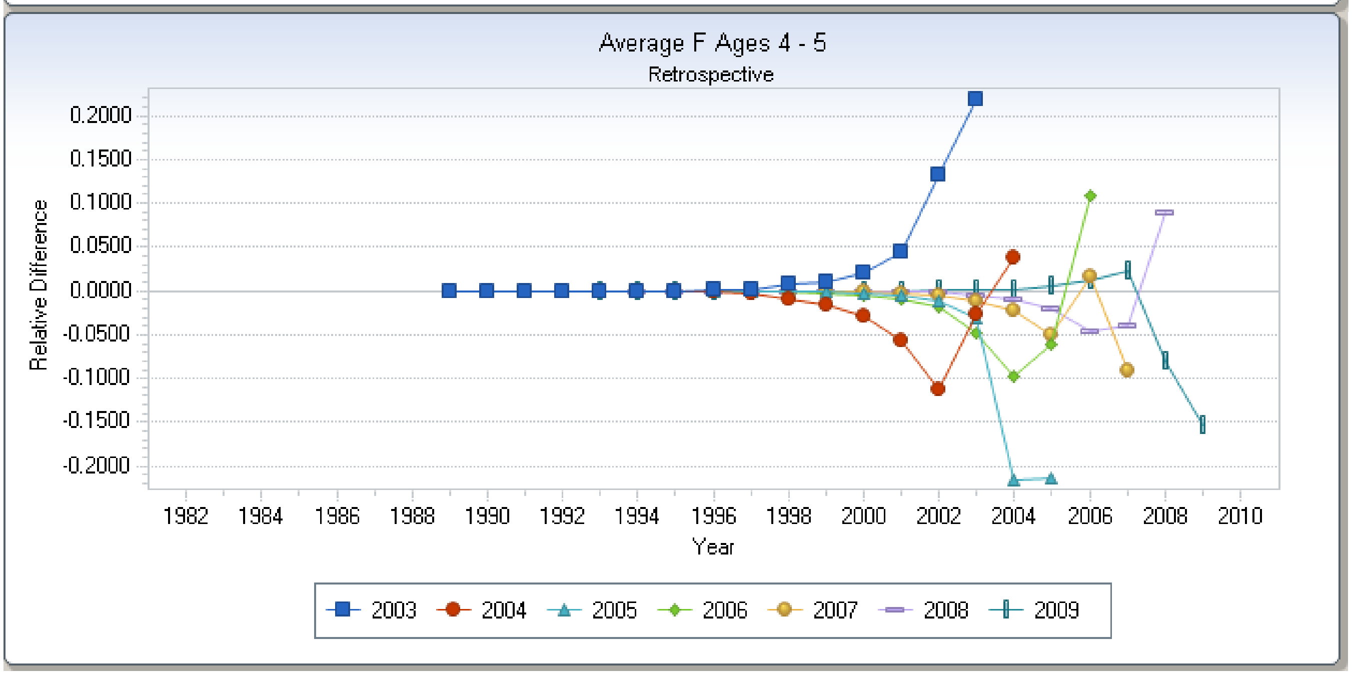
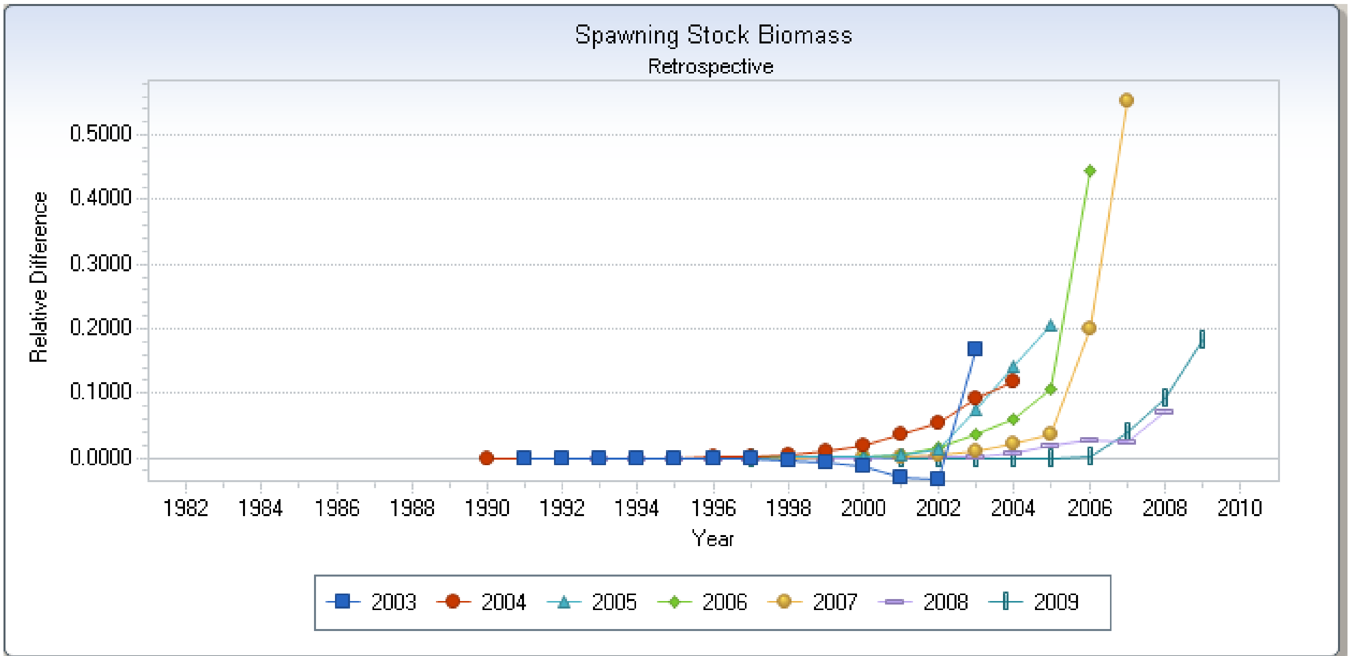


Figure A43. Retrospective patterns (relative difference) in Fishing Mortality (F age 4-5) from Developmental VPA models. Top panel is from the VPA model with M = 0.2; bottom panel is from the VPA model
with M = 0.3.



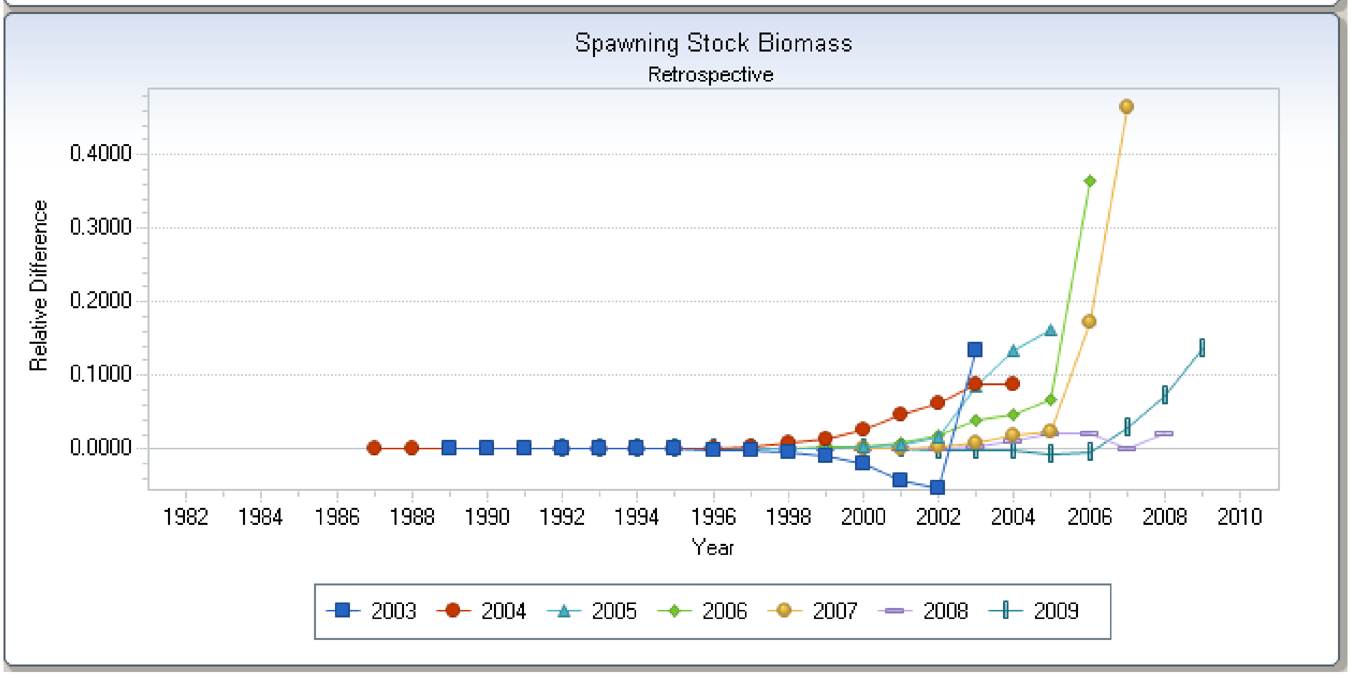
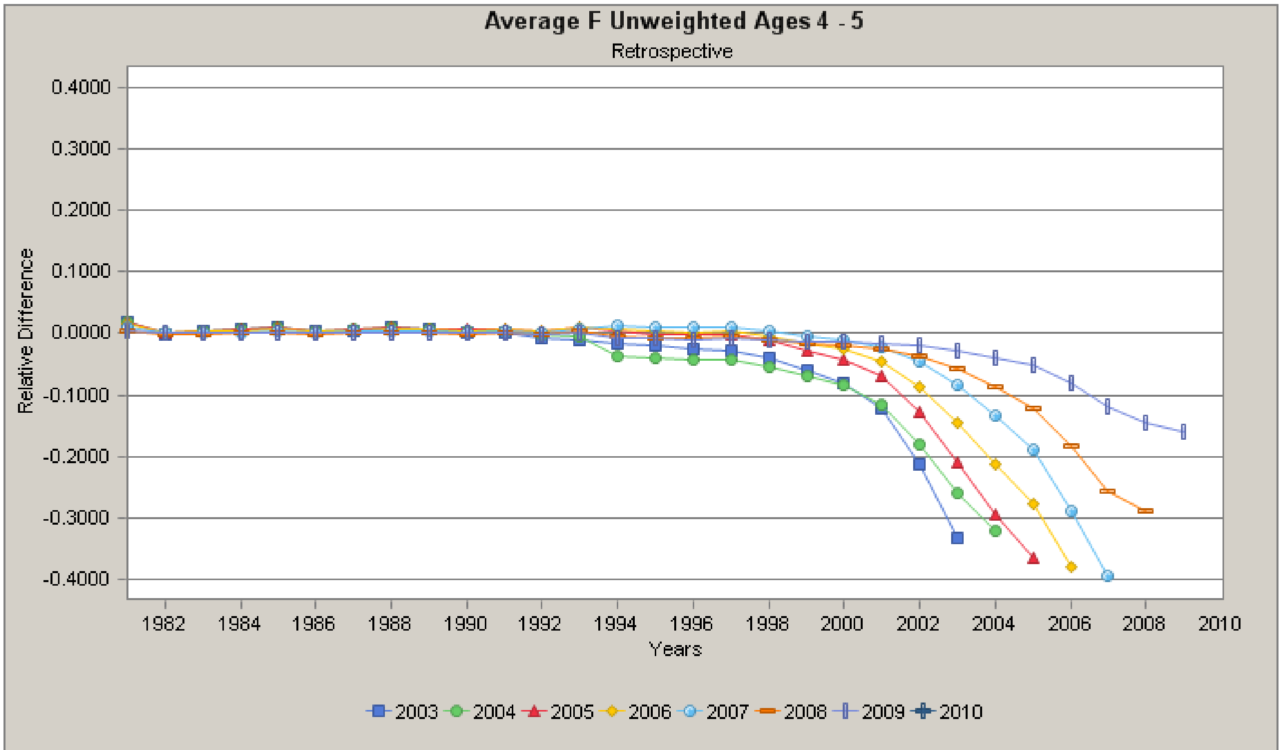


Figure A44. Retrospective patterns (relative difference) in SSB from Developmental VPA models. Top panel is from the VPA model with M = 0.2; bottom panel is from the VPA model with M = 0.3.



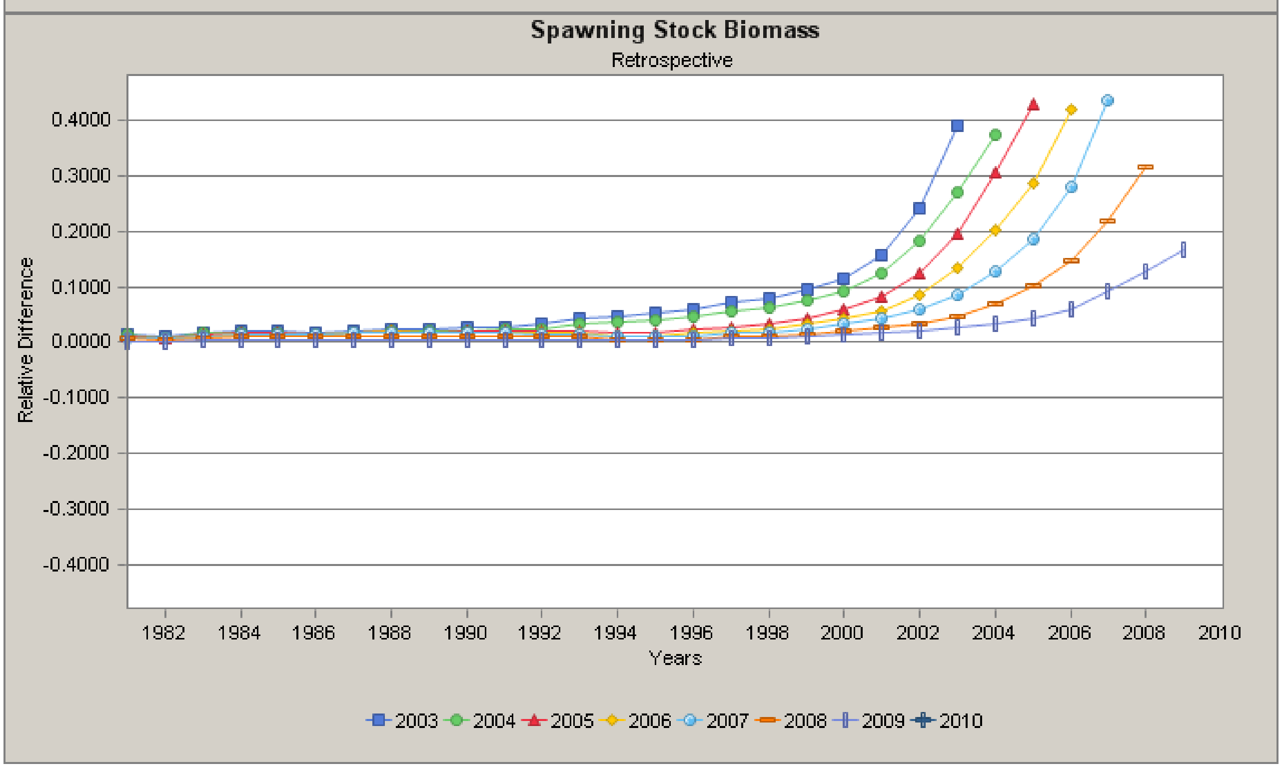


Figure A45. Retrospective patterns (relative difference) in Fishing Mortality and SSB from Developmental ASAP model with M = 0.3.

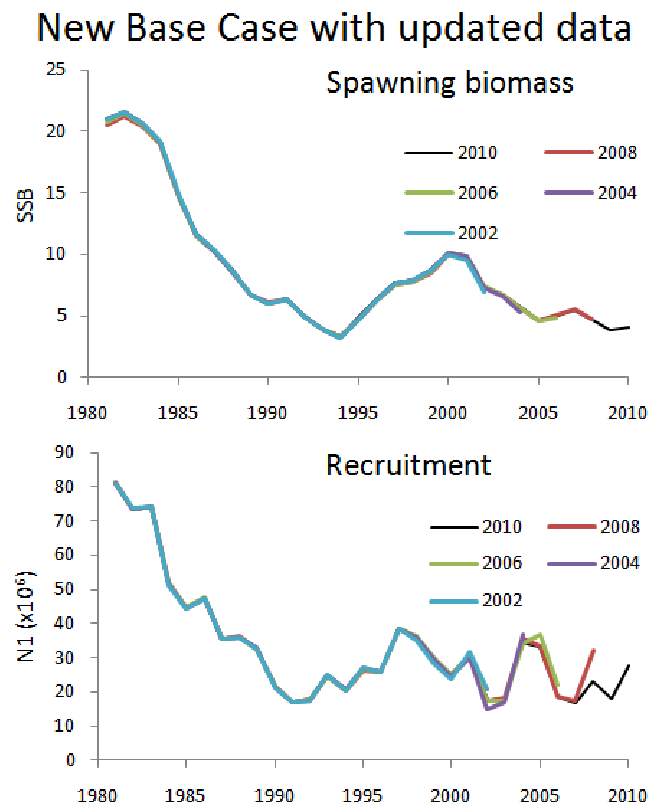


Figure A46. Retrospective patterns (absolute difference) in Spawning Stock Biomass (SSB) and Recruitment (millions of age 1 fish) from the Rademeyer and Butterworth (2011b) ASPM model for SNE/MA winter flounder.

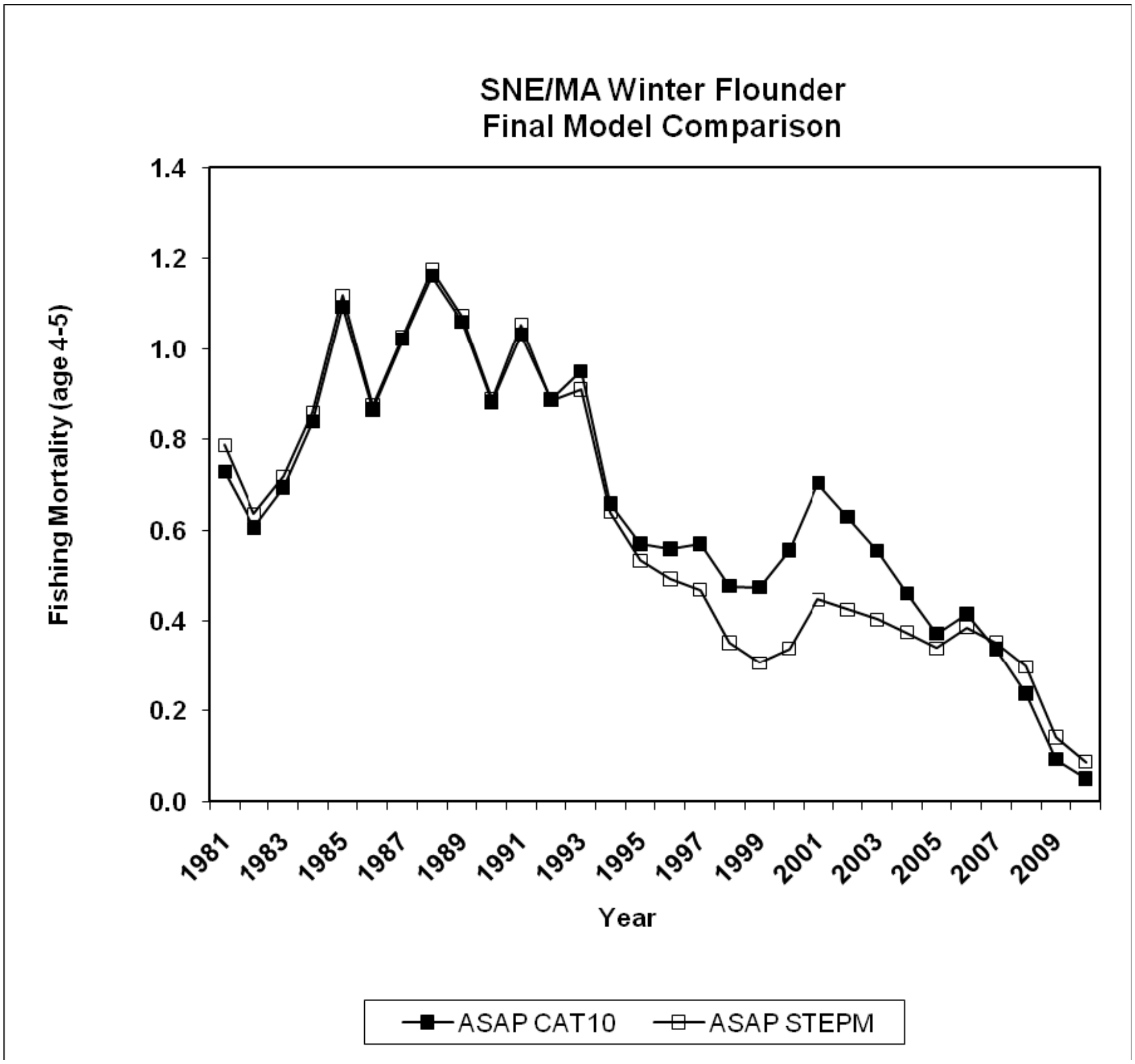


Figure A47. Estimates of Fishing Mortality (age 4-5) from the final ASAP CAT10 and the alternative STEPM model configurations.

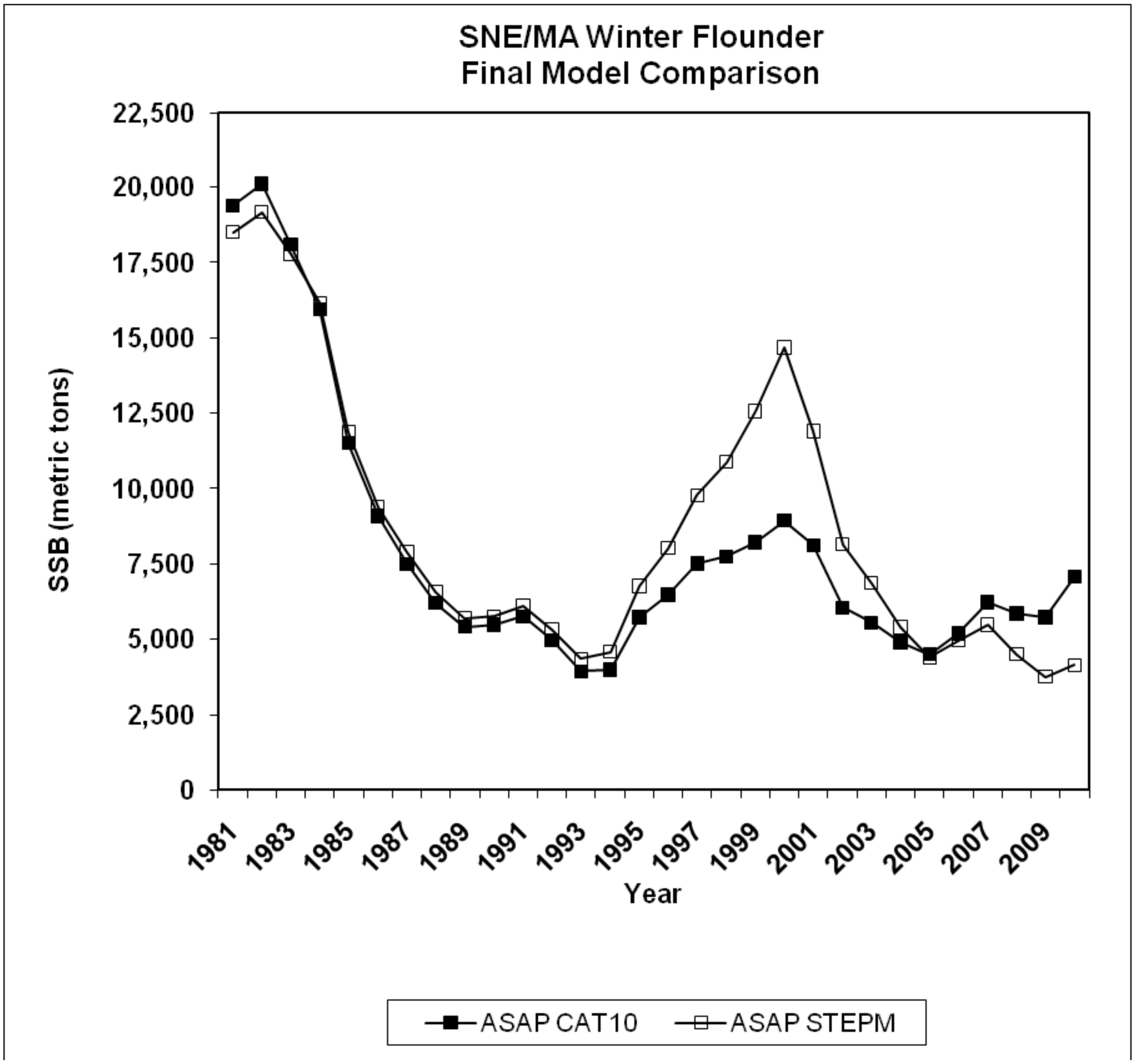


Figure A48. Estimates of Spawning Stock Biomass (SSB) from the final ASAP CAT10 and the alternative STEPM model configurations.

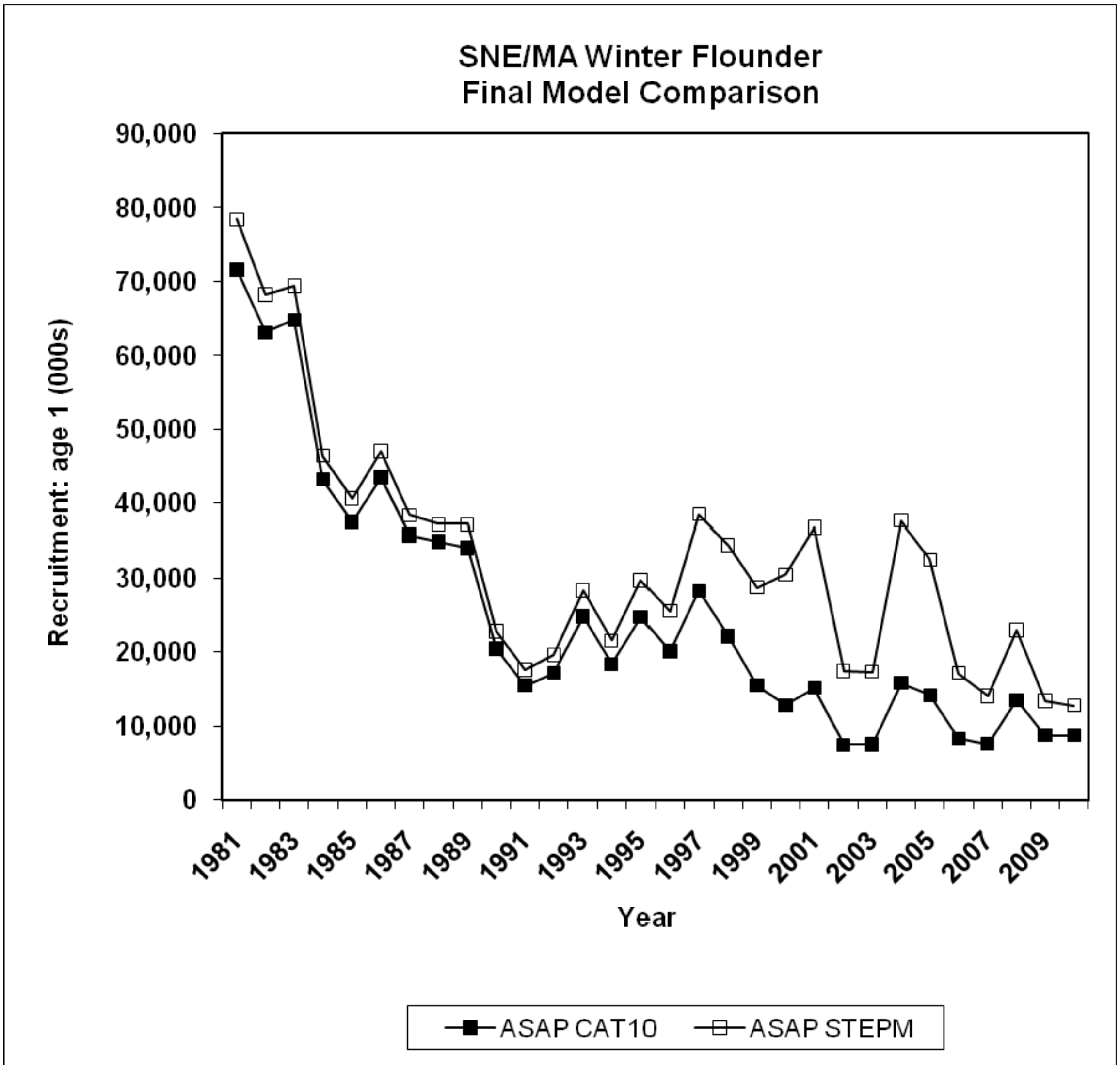


Figure A49. Estimates of Recruitment at age 1 (000s) from the final ASAP CAT10 and the alternative STEPM model configurations.

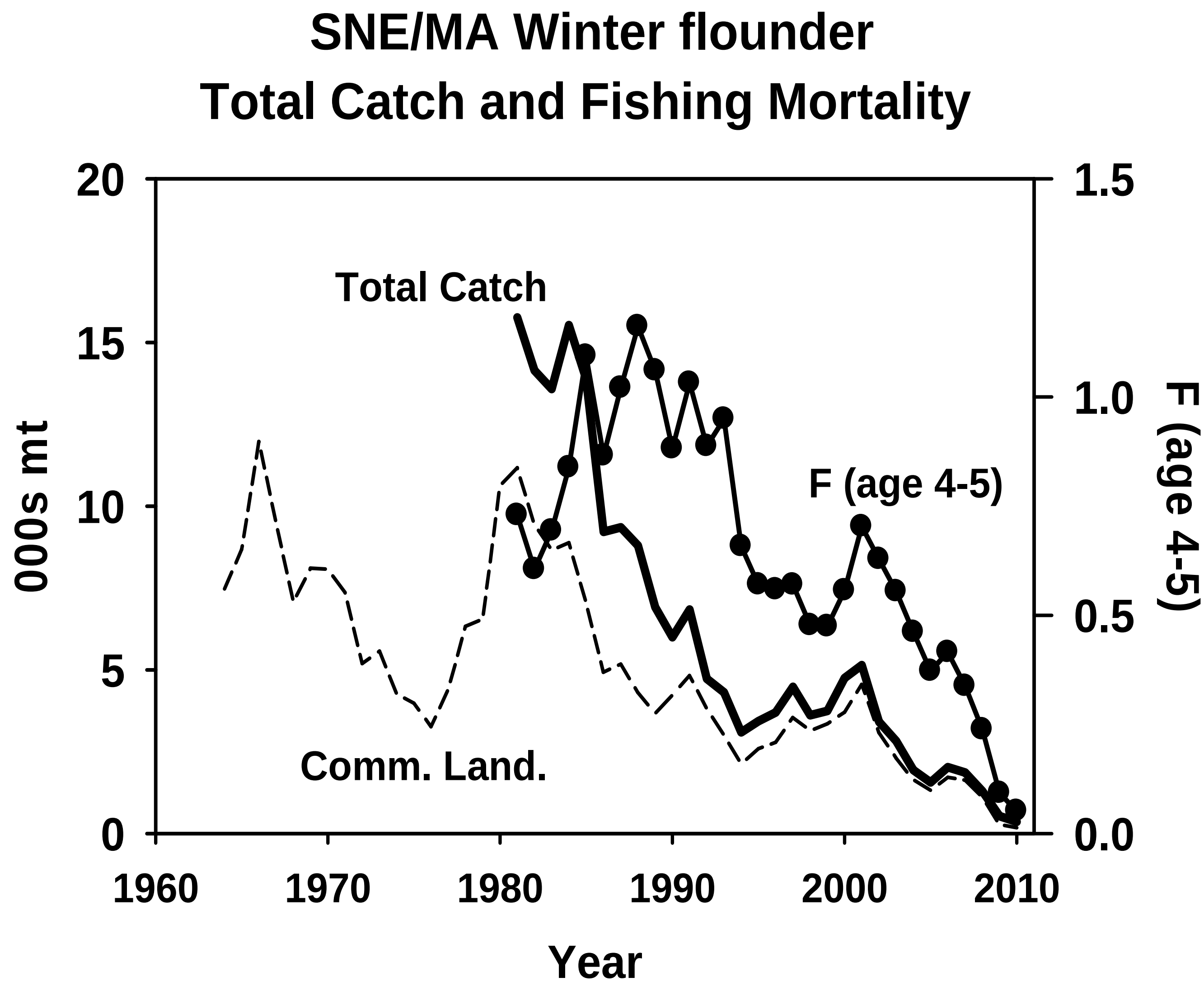


Figure A50. Total catch (landings and discards, 000s mt), commercial landings (000s mt), and fishing mortality rate (F age 4-5) for SNE/MA winter flounder.

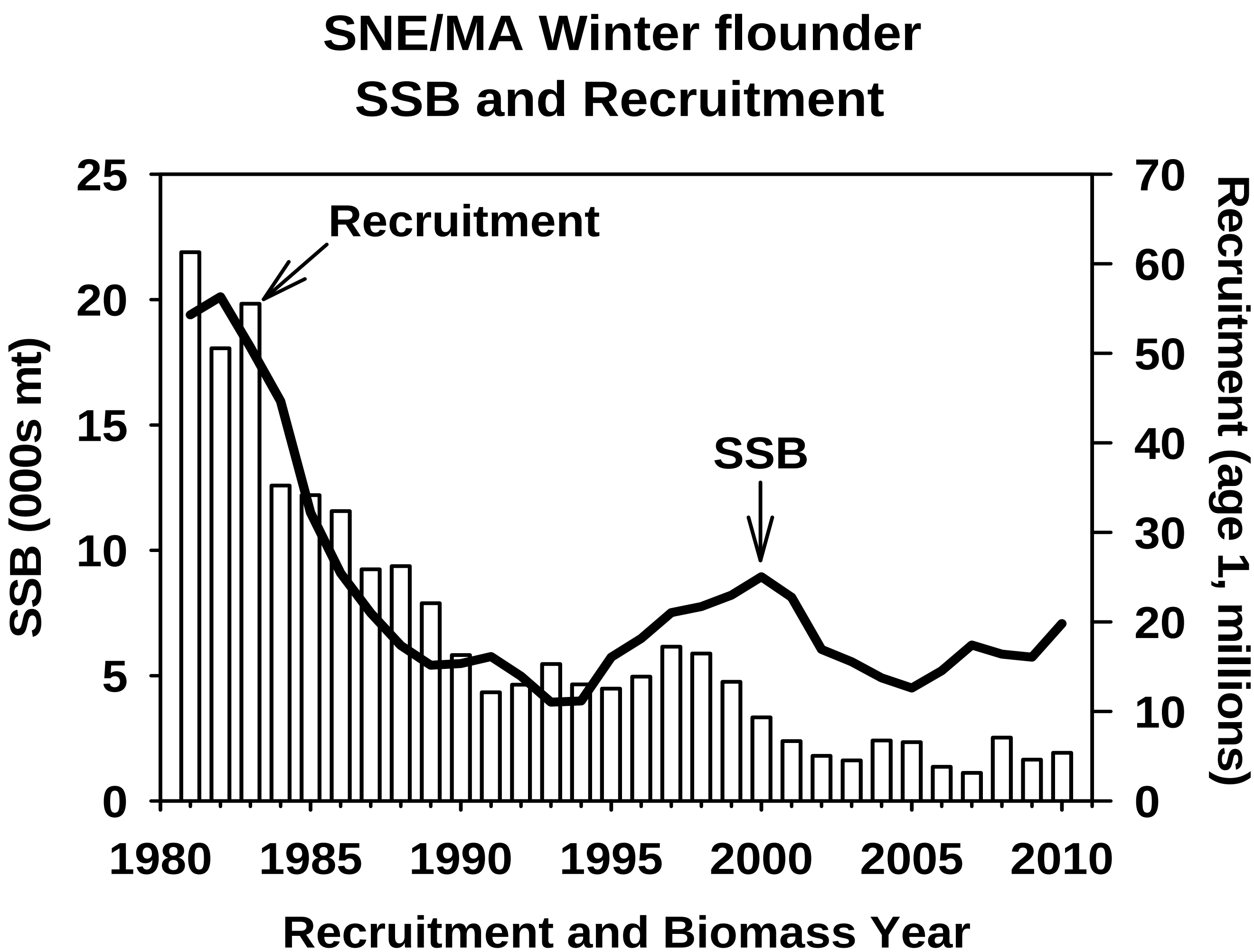


Figure A51. Spawning stock biomass (SSB, 000s mt, solid line) and recruitment (millions of fish at age-1, vertical bars) for SNE/MA winter flounder.

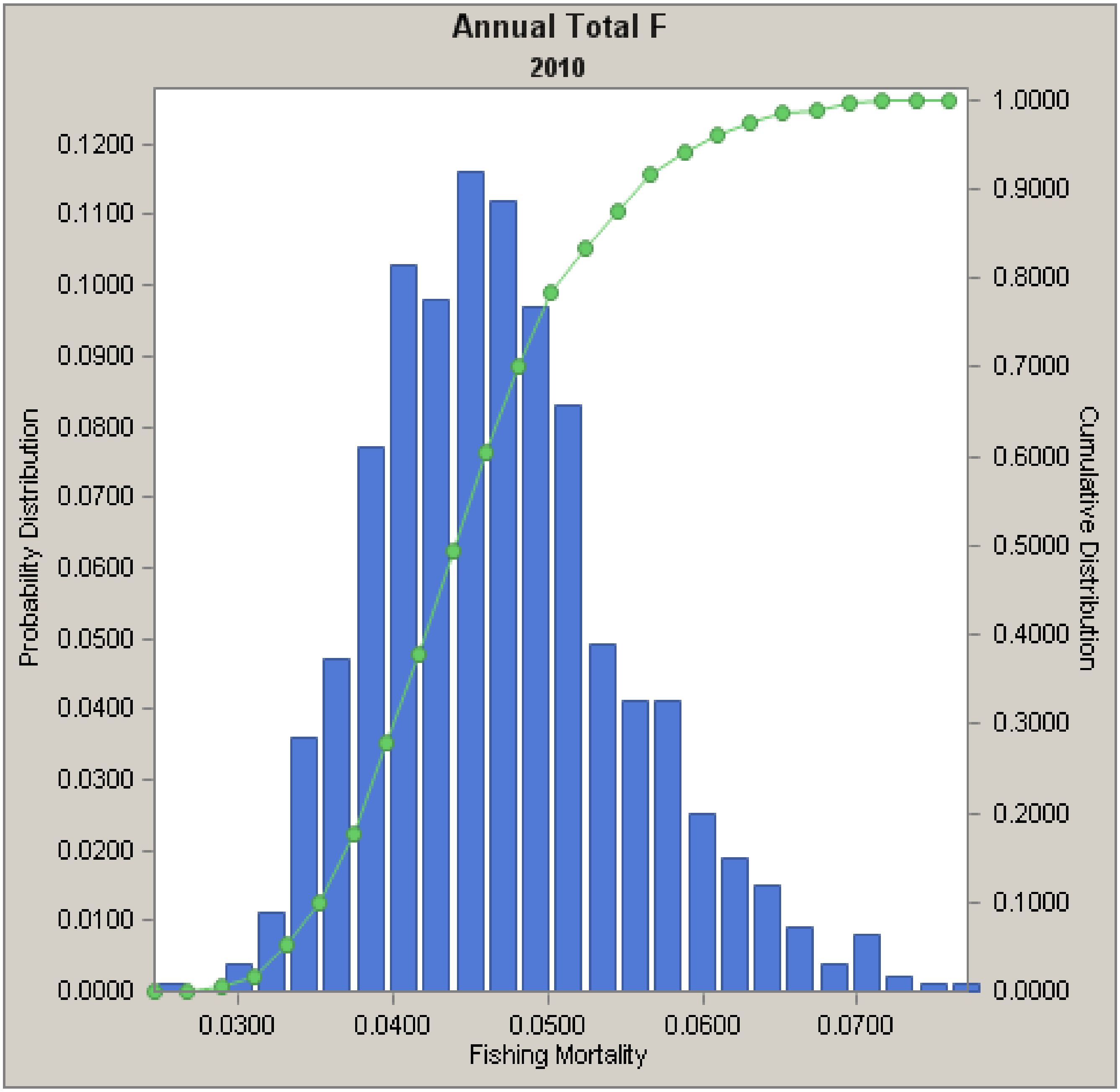


Figure A52. MCMC distribution of the estimate of the 2010 Fishing Mortality of SNE/MA winter flounder.

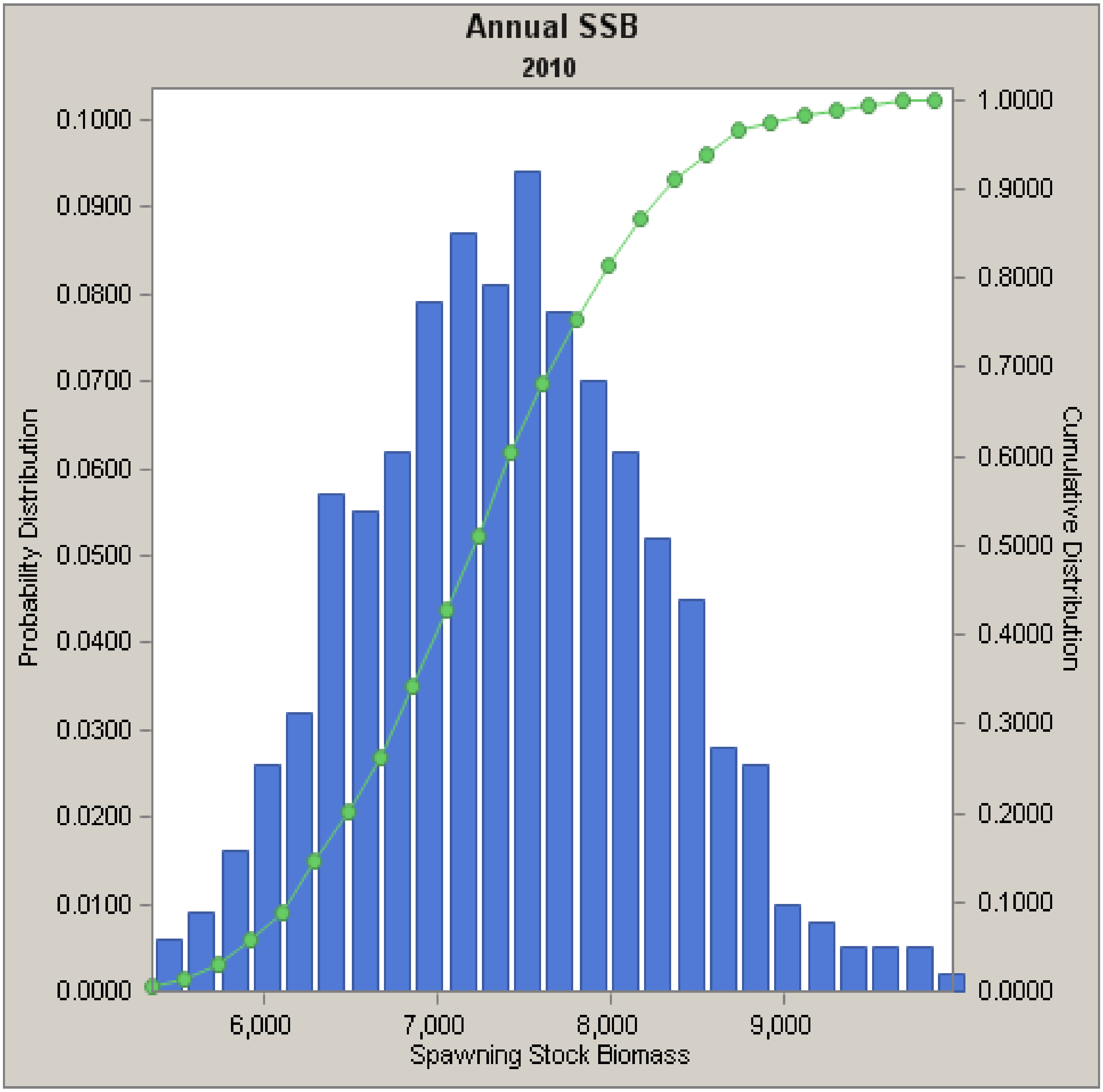


Figure A53. MCMC distribution of the estimate of the 2010 Spawning Stock Biomass (SSB) SNE/MA winter flounder.

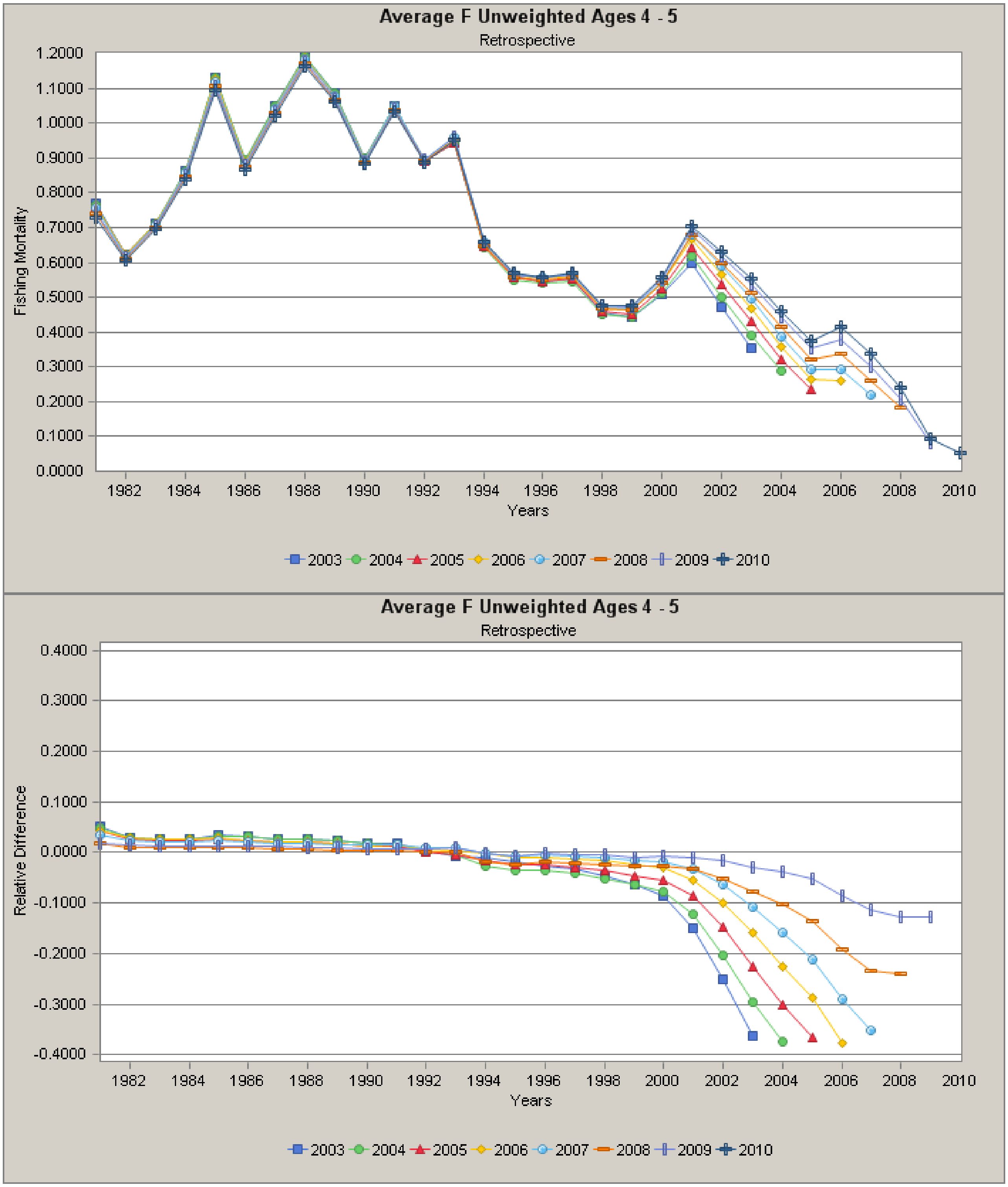


Figure A54. Retrospective errors in estimates of Fishing Mortality (F age 4-5) for SNE/MA winter flounder.

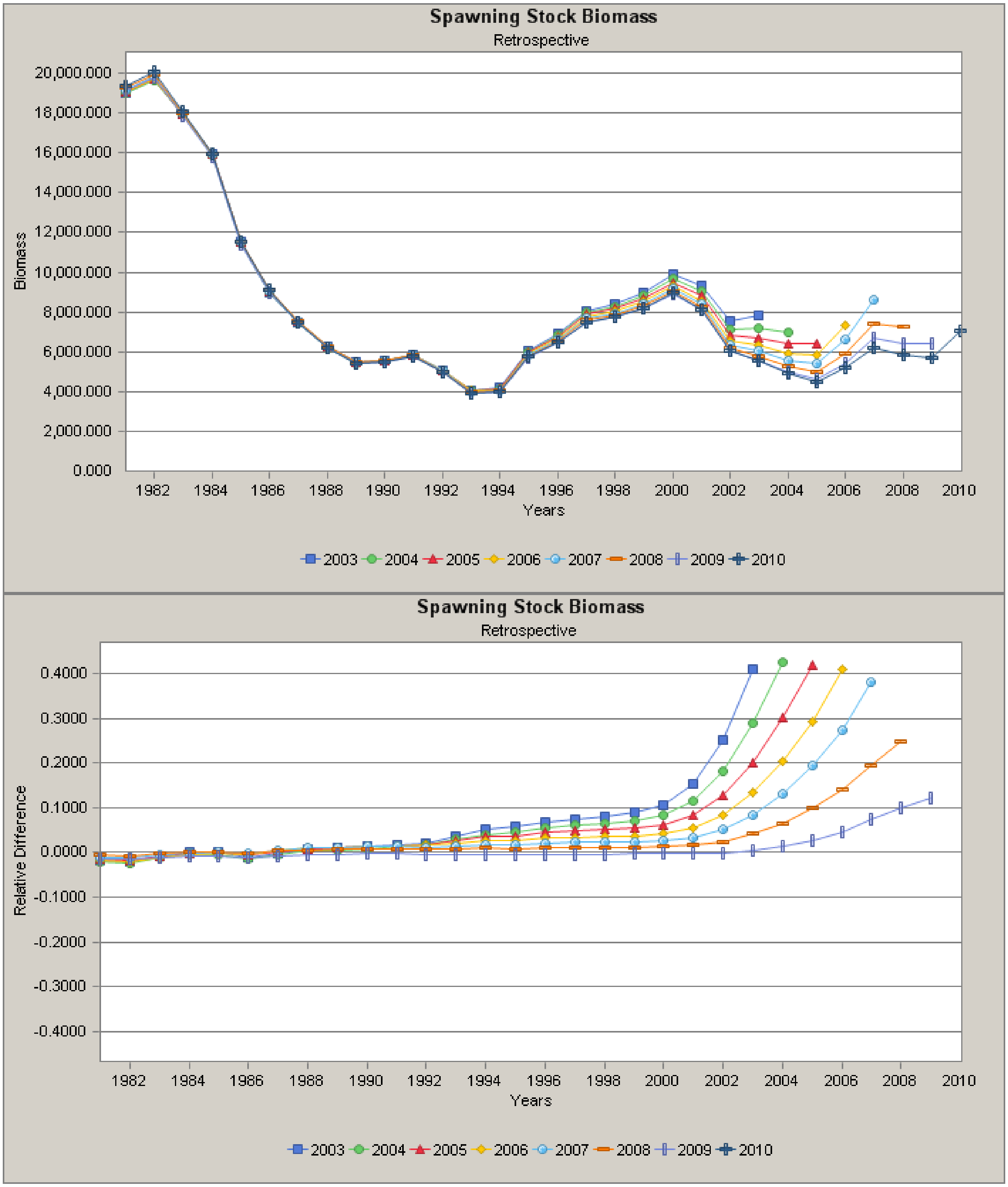


Figure A55. Retrospective errors in estimates of Spawning Stock Biomass for SNE/MA winter flounder.

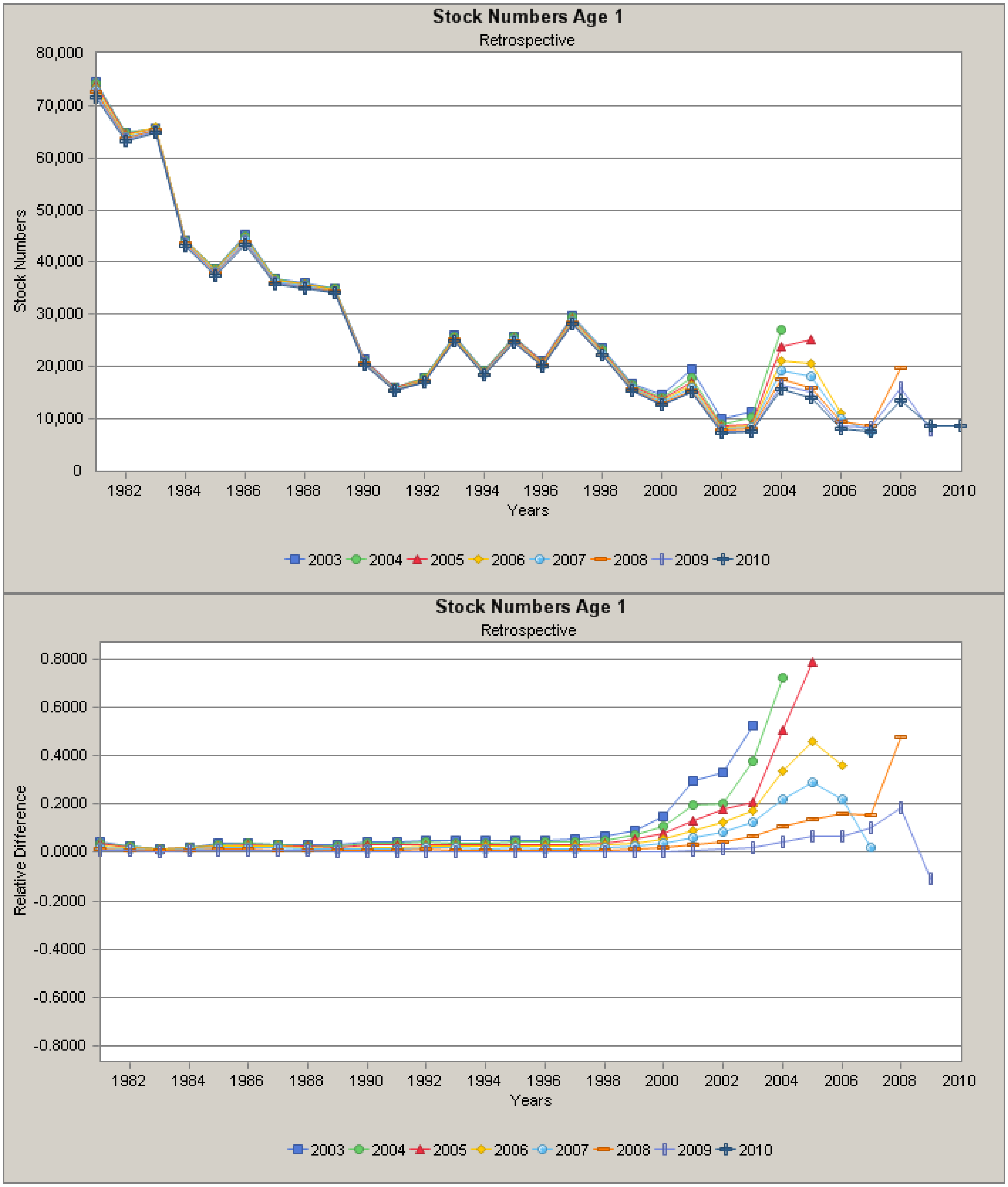


Figure A56. Retrospective errors in estimates of Recruitment at age 1 for SNE/MA winter flounder.

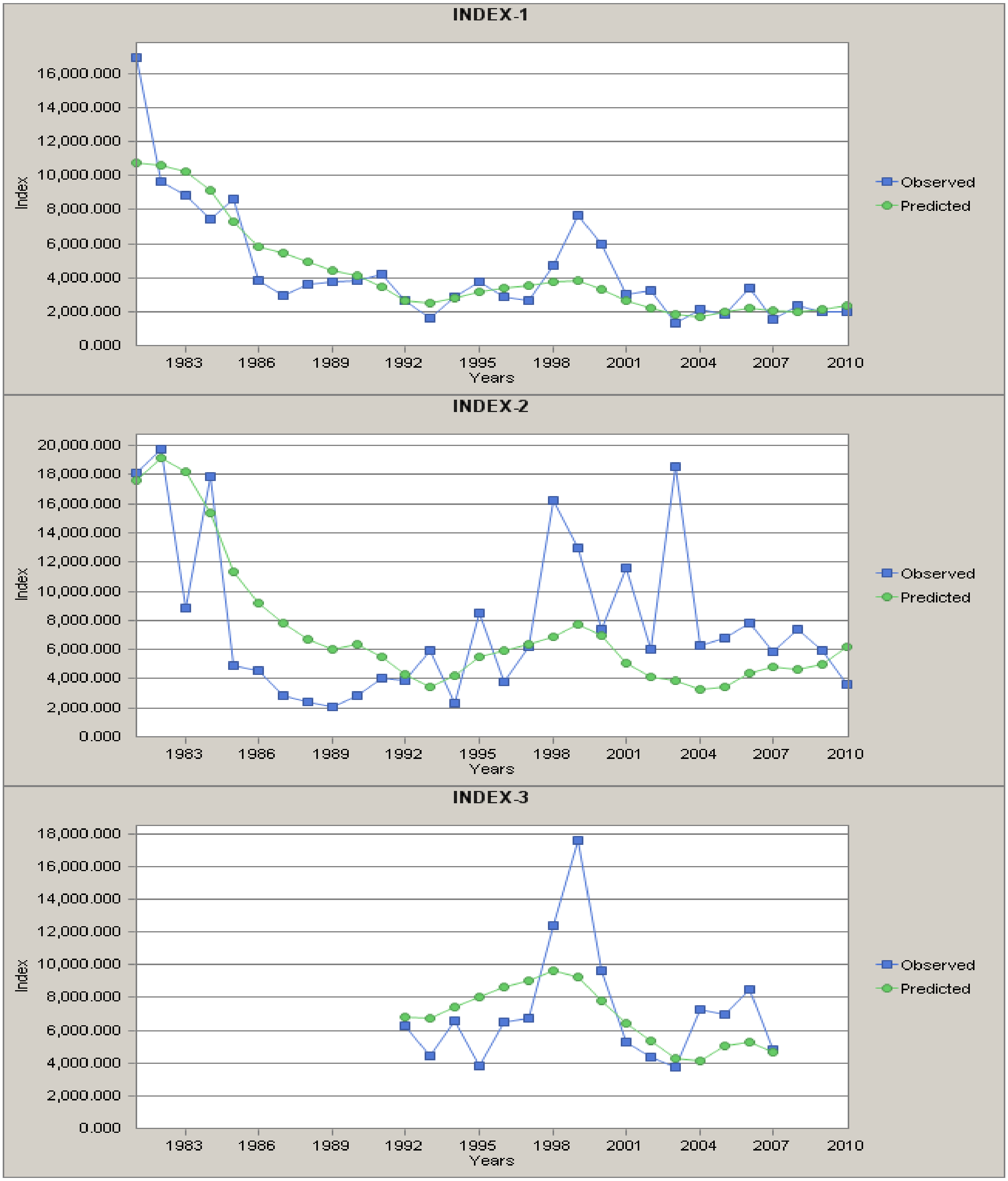


Figure A57. Model fit to the NEFSC Spring (Index 1), Fall (Index 2), and Winter (Index 3) survey aggregate indices of abundance, expressed as absolute swept-area numbers (millions).

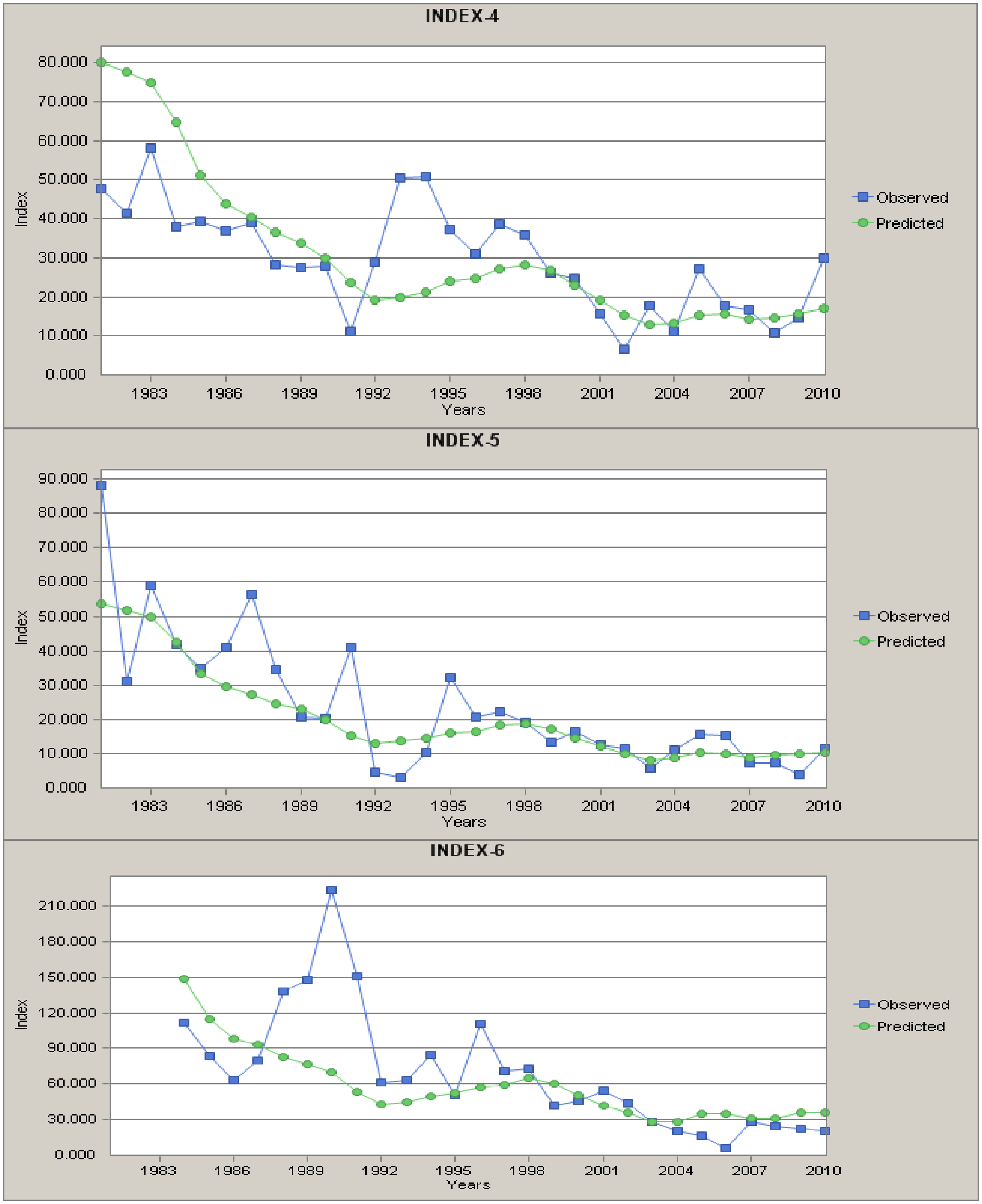


Figure A58. Model fit to the MADMF Spring (Index 4), RIDFW Spring (Index 5), and CTDEP Spring (Index 6) survey aggregate indices of abundance.

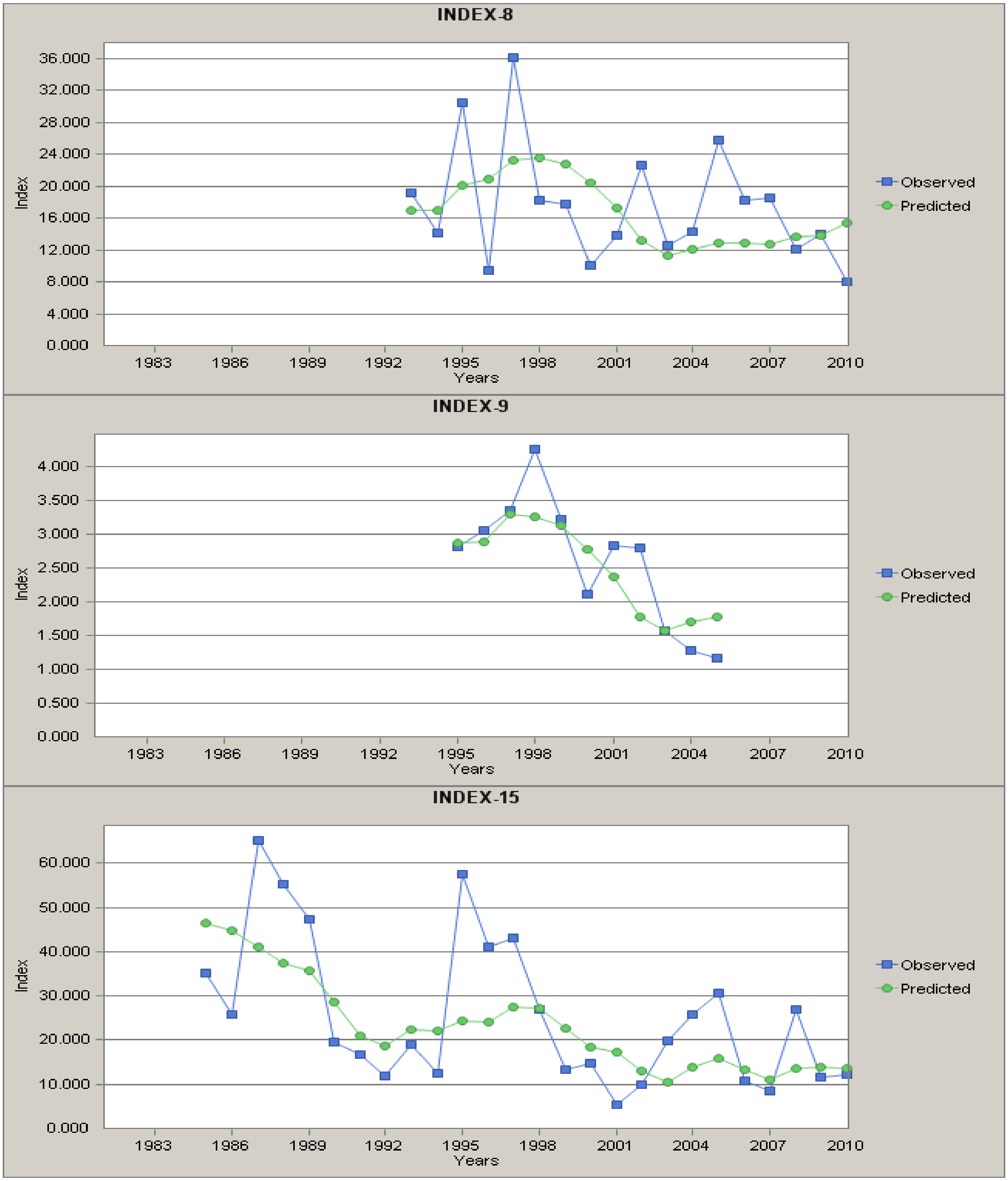


Figure A59. Model fit to the NJDFW Oceans (Index 8), NJDFW Rivers (Index 9), and URIGSO (Index 15) survey aggregate indices of abundance.

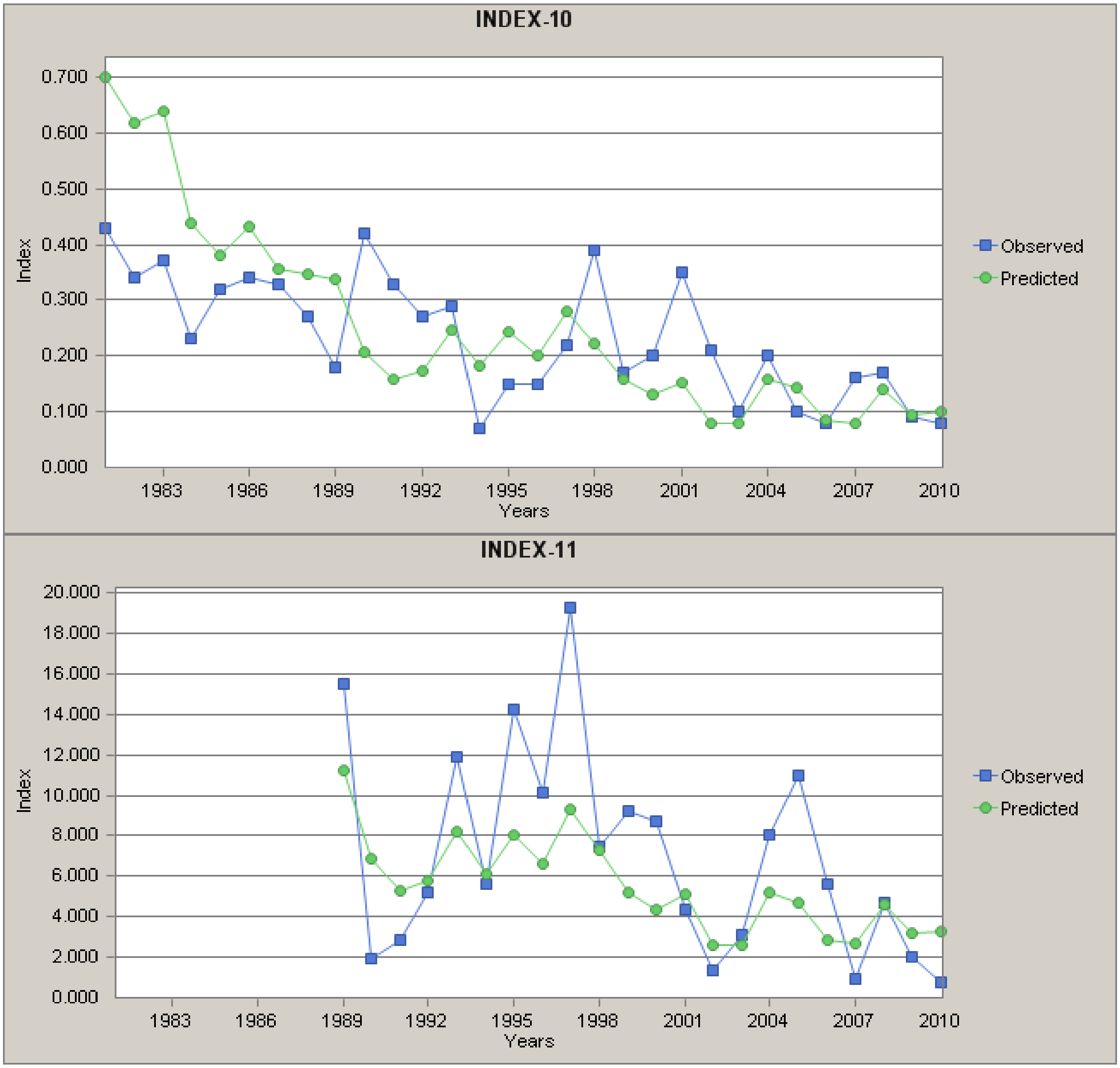


Figure A60. Model fit to the MADMF Seine (Index 10) and CTDEP Seine (Index 11) survey recruitment indices.

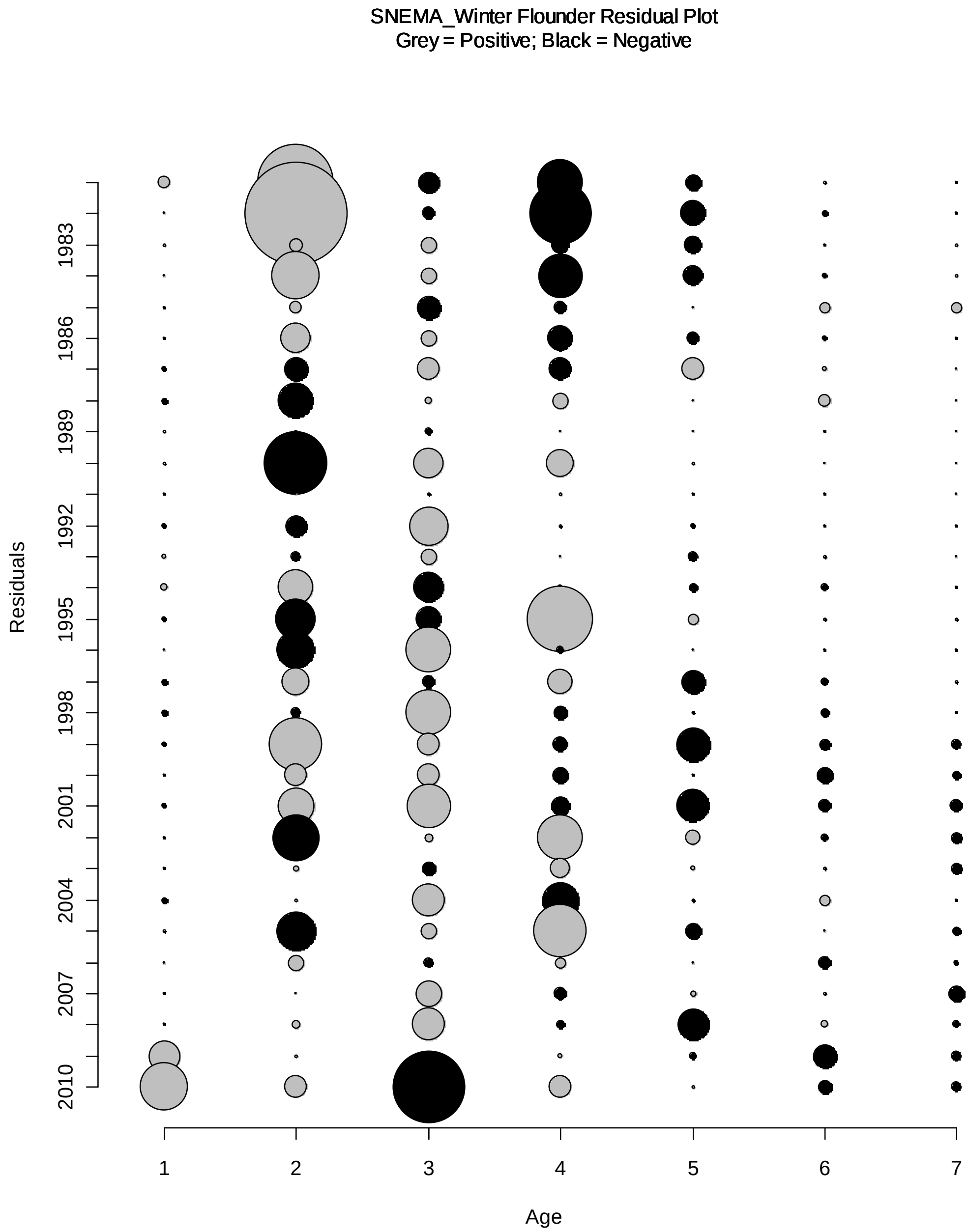


Figure A61. Model fit simple residuals (observed minus predicted proportion at age) for the fishery age compositions for SNE/MA winter flounder.

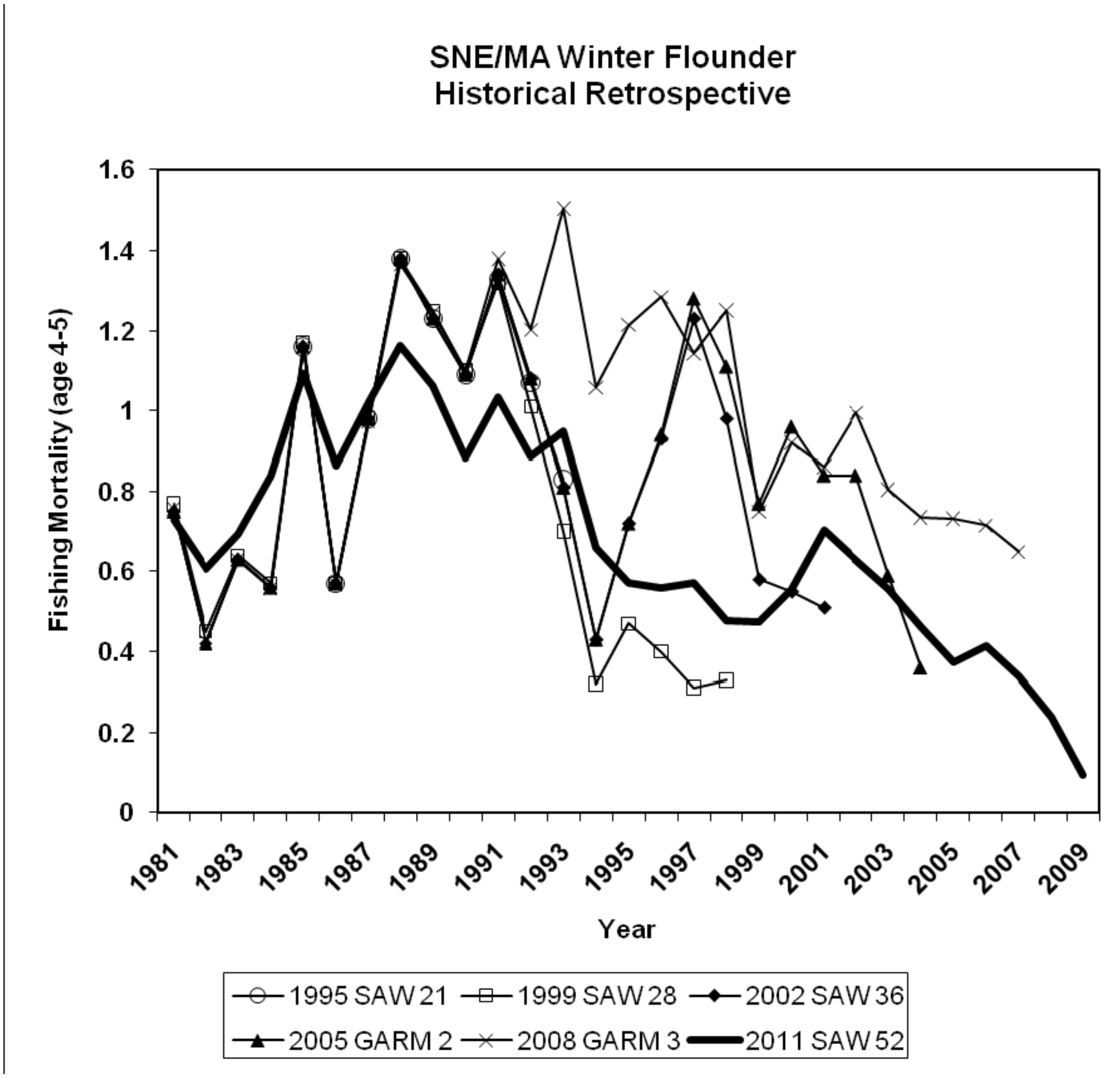


Figure A62. Historical retrospective in estimates of Fishing Mortality (age 4-5) for SNE/MA winter flounder.

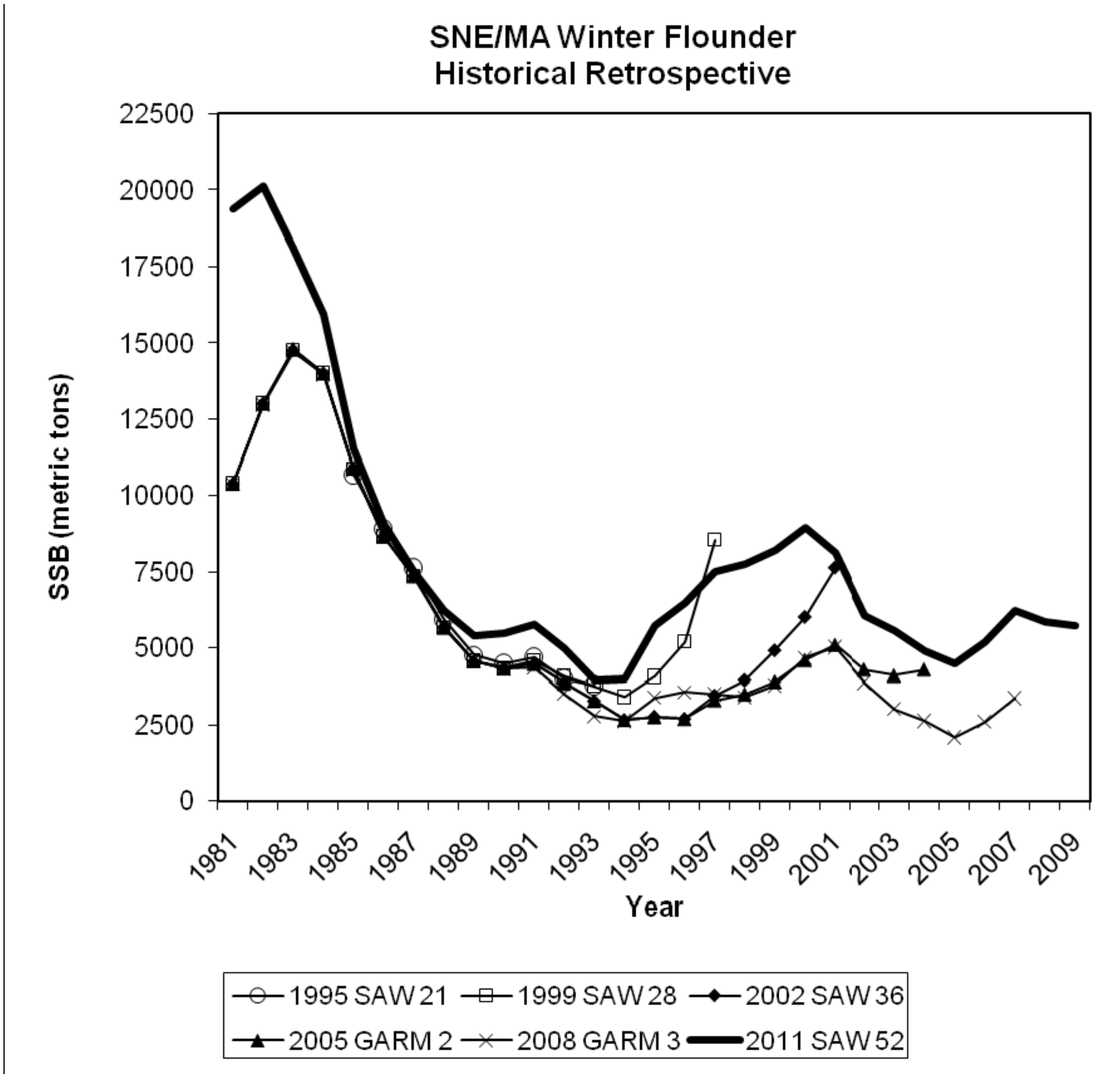


Figure A63. Historical retrospective in estimates of Spawning Stock Biomass (SSB) for SNE/MA winter flounder.

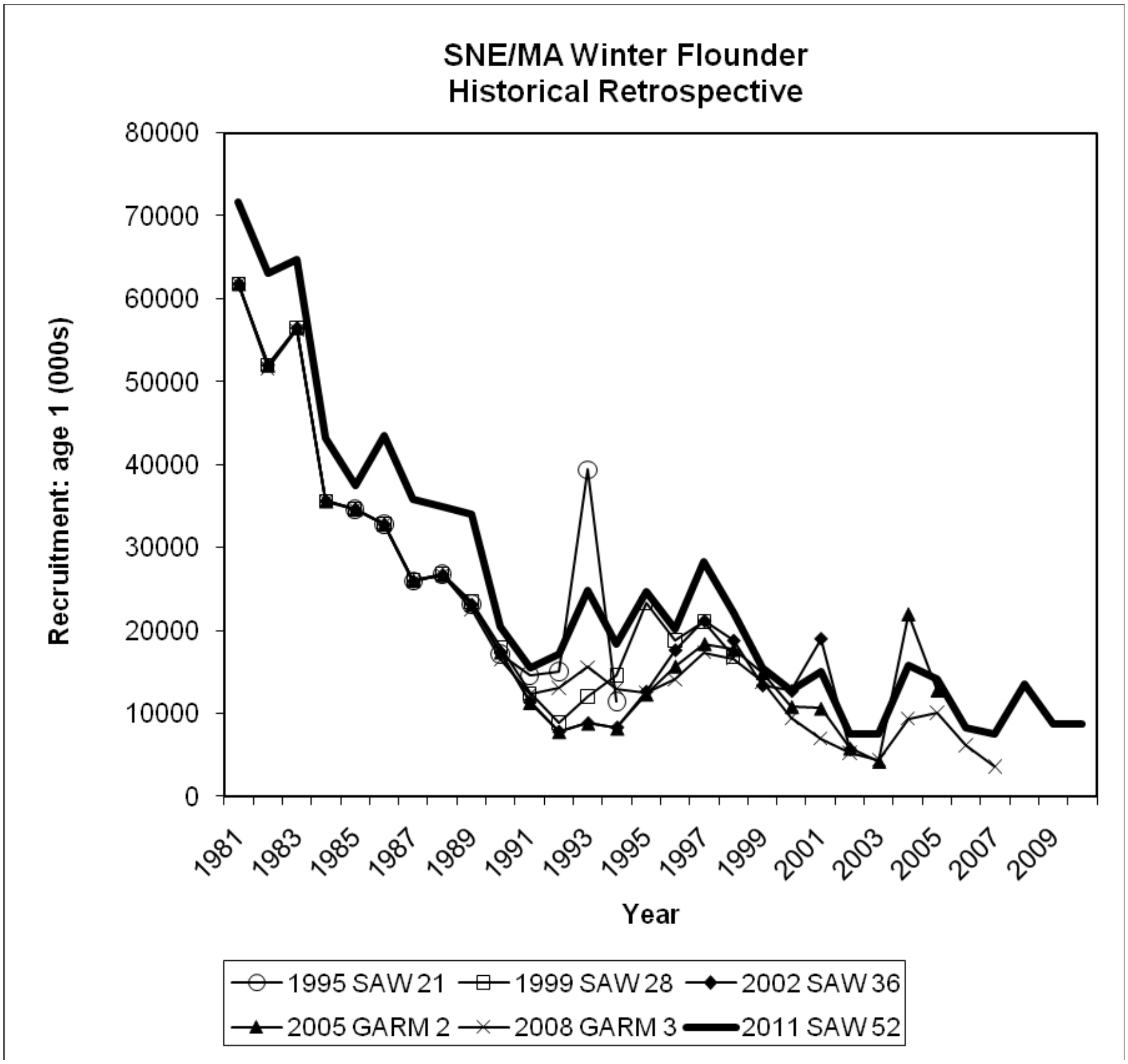


Figure A64. Historical retrospective in estimates of Recruitment at age 1 (000s) for SNE/MA winter flounder.

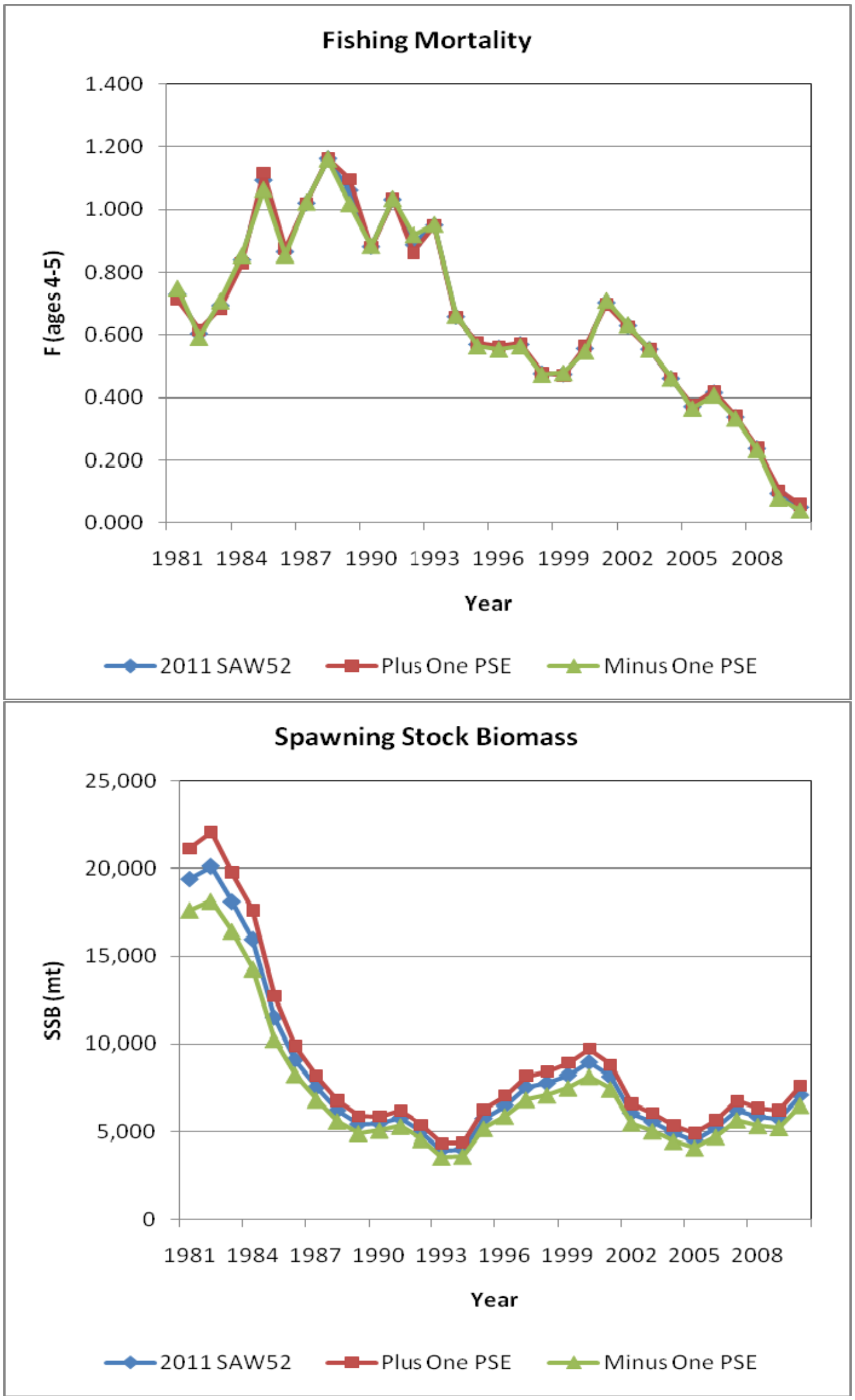


Figure A65. Trends in SNE/MA winter flounder Fishing Mortality (F age 4-5) and Spawning Stock Biomass (SSB) for final models with Plus One Proportional Standard Error (PSE) and Minus One PSE total catch: Response to TOR4.

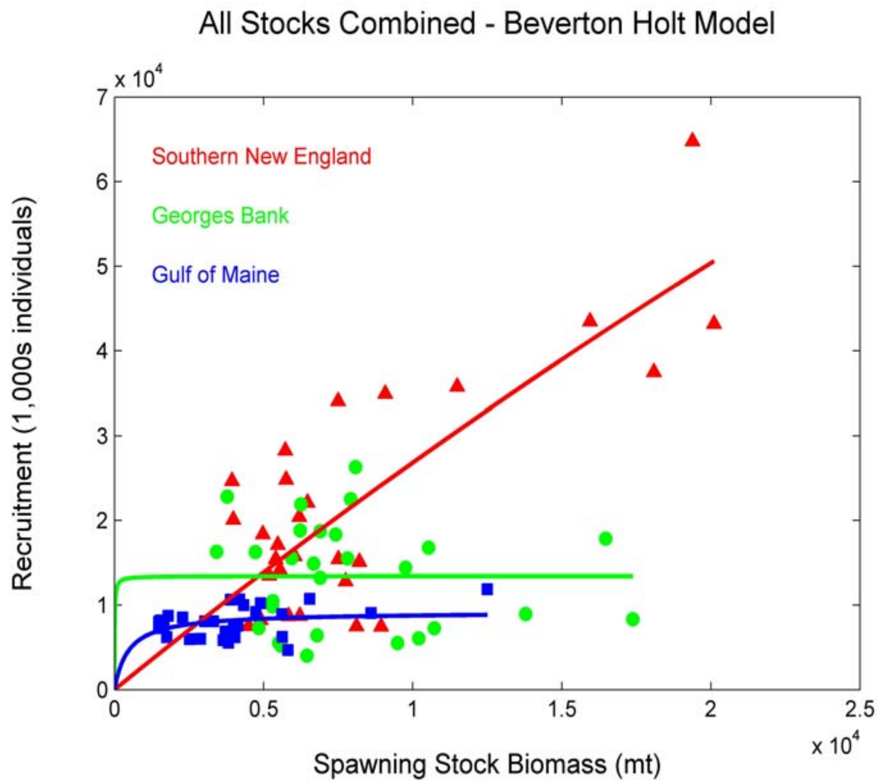


Figure A66. Comparison of stock-recruitment data and standard Beverton-Holt stock-recruitment models for the three U.S. winter flounder stocks.

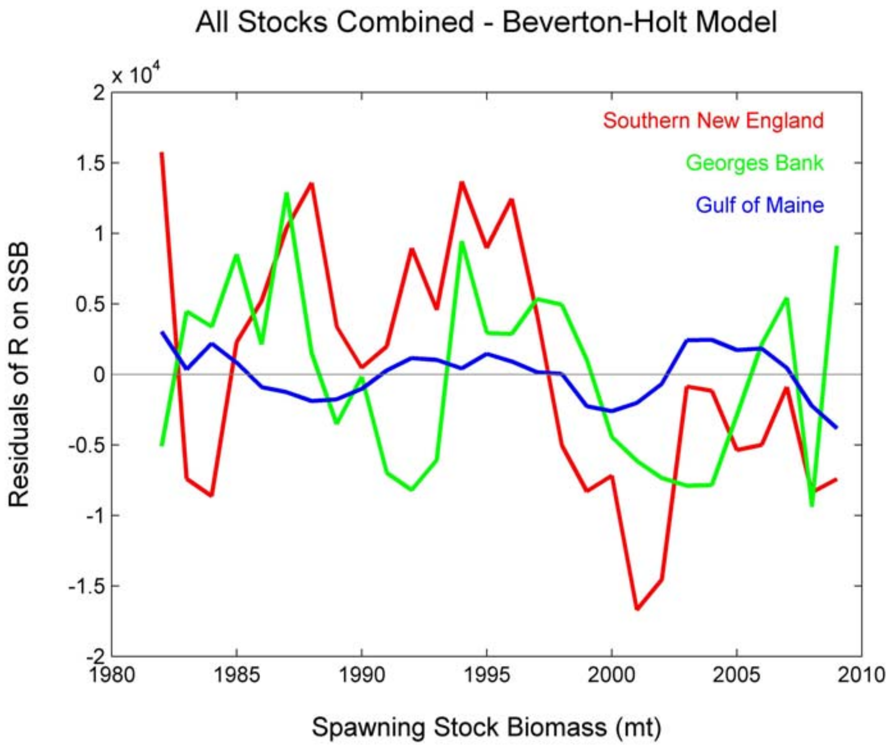


Figure A67. Comparison of the residuals of the stock-recruitment relationships for the three U.S. winter flounder stocks based on the standard Beverton-Holt stock-recruitment model.

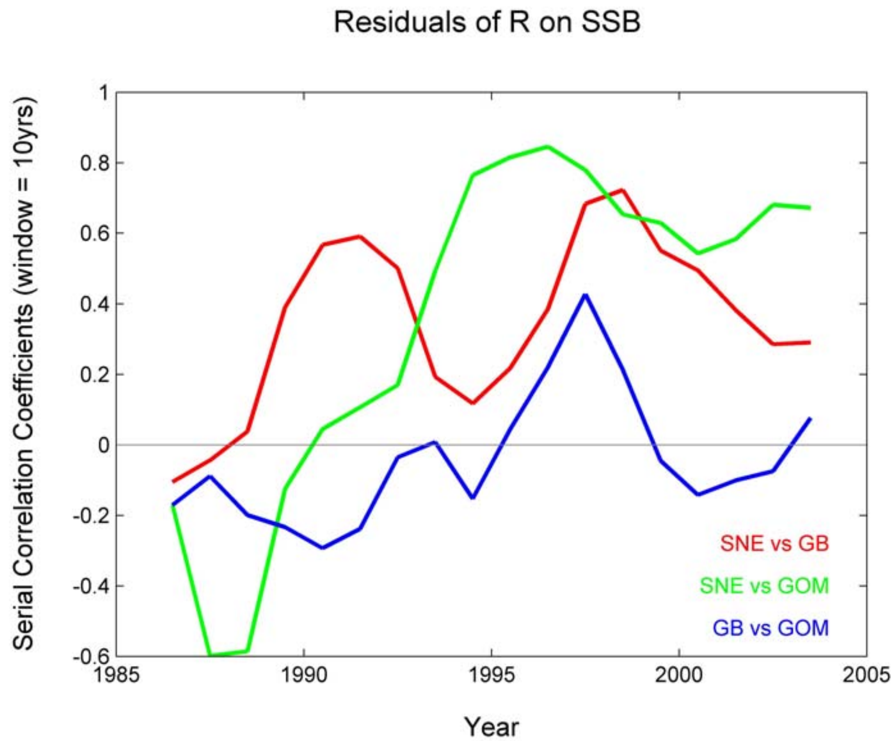


Figure A68. Serial correlation of the residuals of the stock recruitment relationship making the three pairwise comparisons: SNE vs. GB, SNE vs. GOM, and GB vs. GOM. Window for serial correlations set at 10 years.

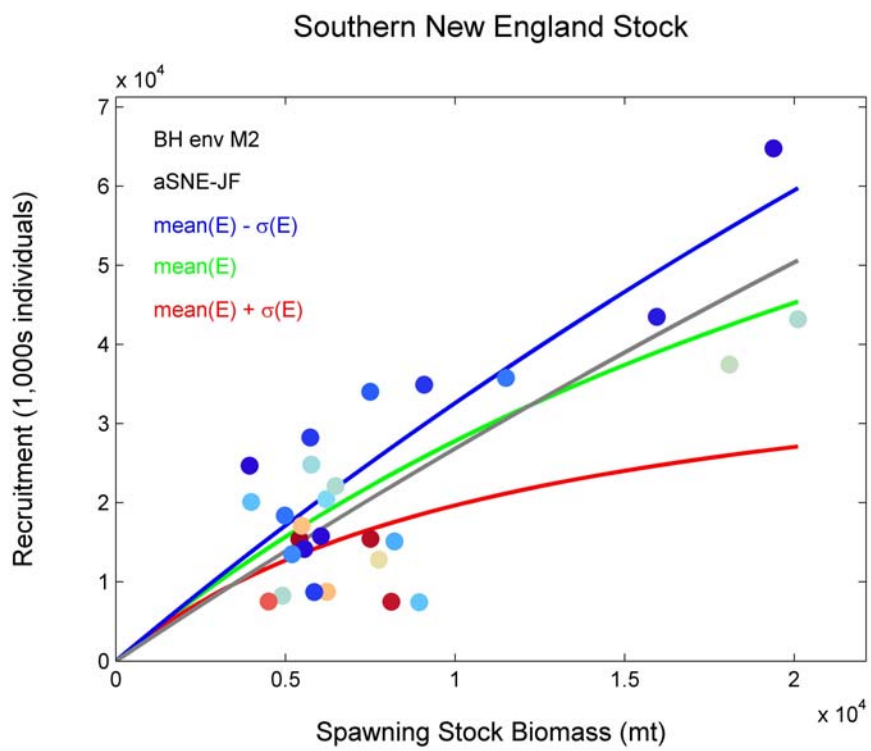


Figure A69. Environmentally-explicit stock recruitment relationships for SNE/MA winter flounder. The best overall environmental model is shown as is the standard model (gray). Symbols are color coded to the value of the environmental variable and model predictions for mean environment and ± 1 standard deviation of the environmental variable are shown. The specific model and environmental variable are noted in the upper left hand corner (see Tables A39-A40; Hare MS 2011).

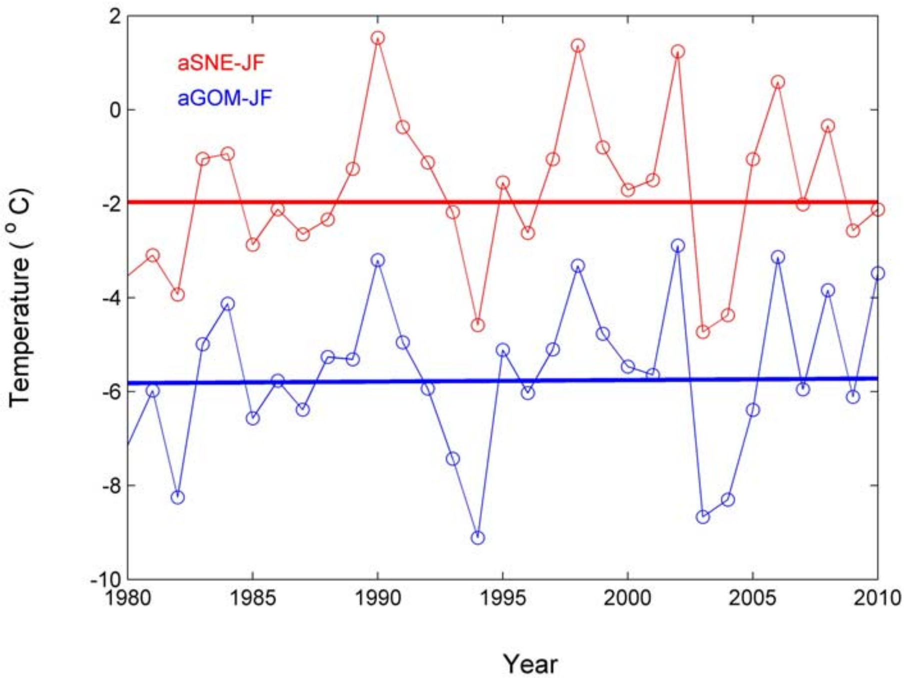
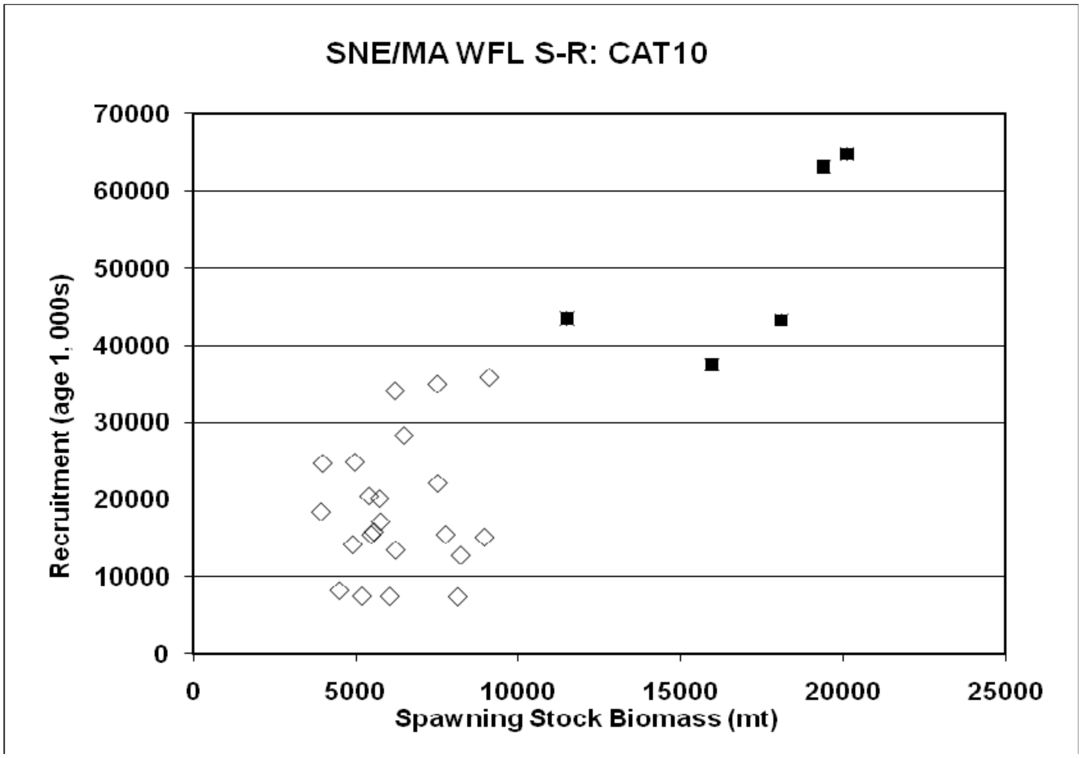


Figure A70. Time series of winter air temperature over Southern New England and the Gulf of Maine for the period of the assessment. The lines represent the linear regression; the slopes of both were not significantly different than zero.



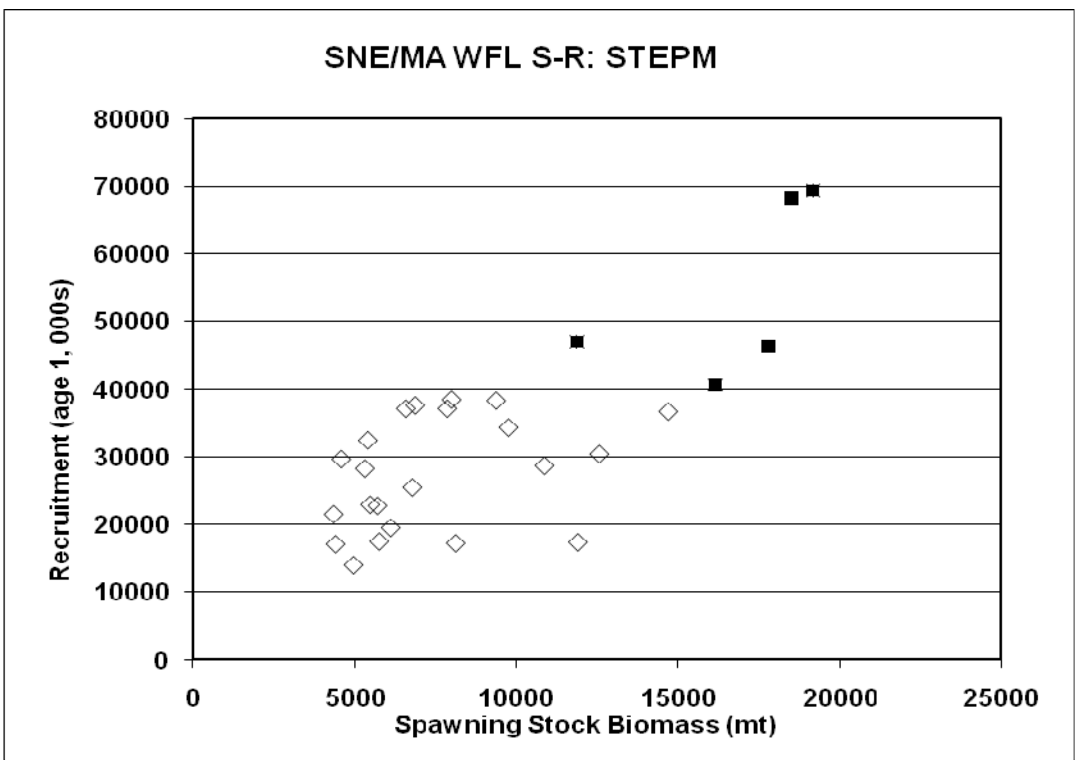


Figure A71. Stock-recruitment estimates from the final ASAP CAT10 model and alternative STEPM model. Five largest year classes (prior for recruitment) plotted in filled boxes.

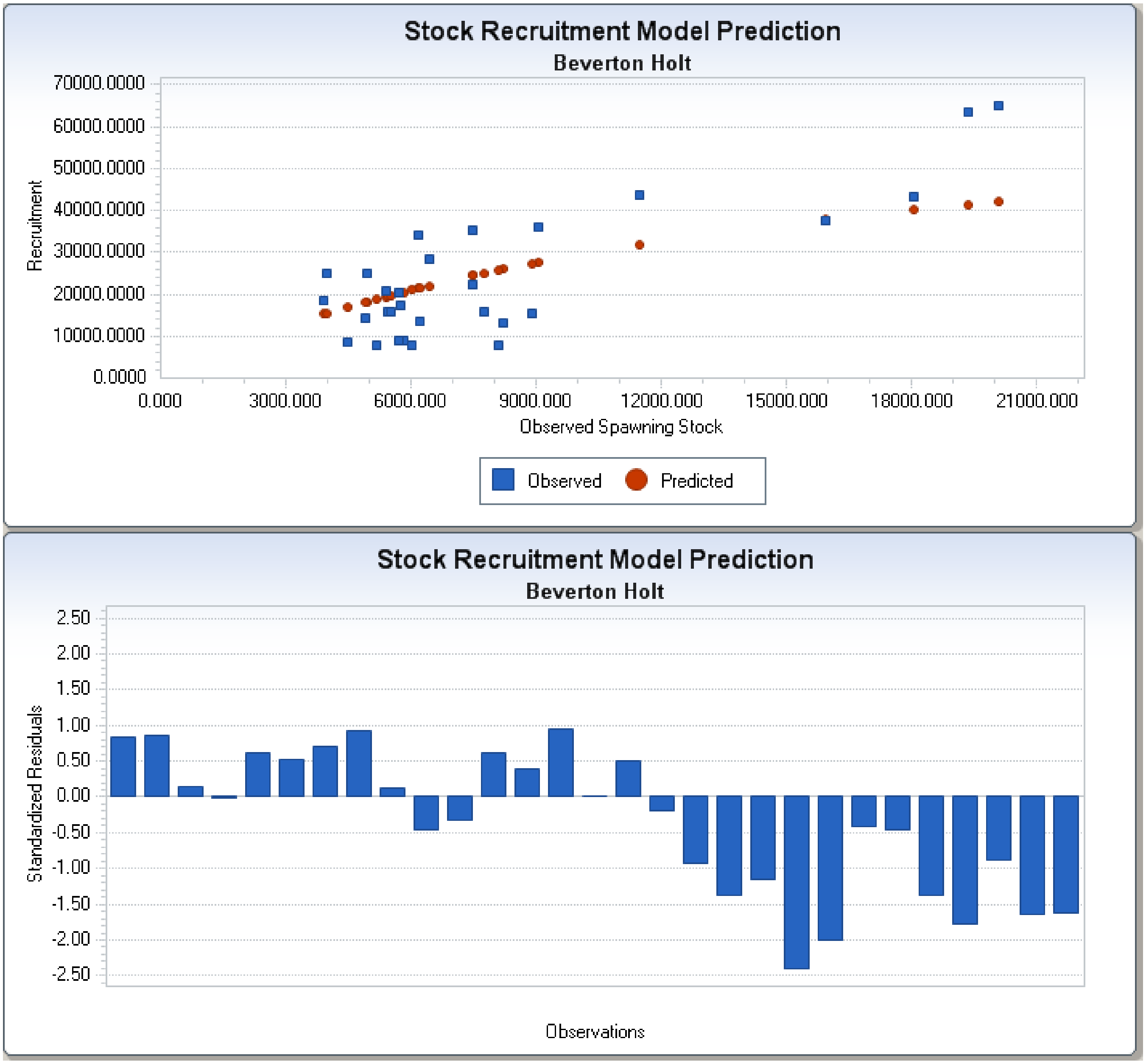


Figure A72. Stock-recruitment model fit with steepness prior (h = 0.8, SE = 0.09) for the ASAP CAT10 model estimates.

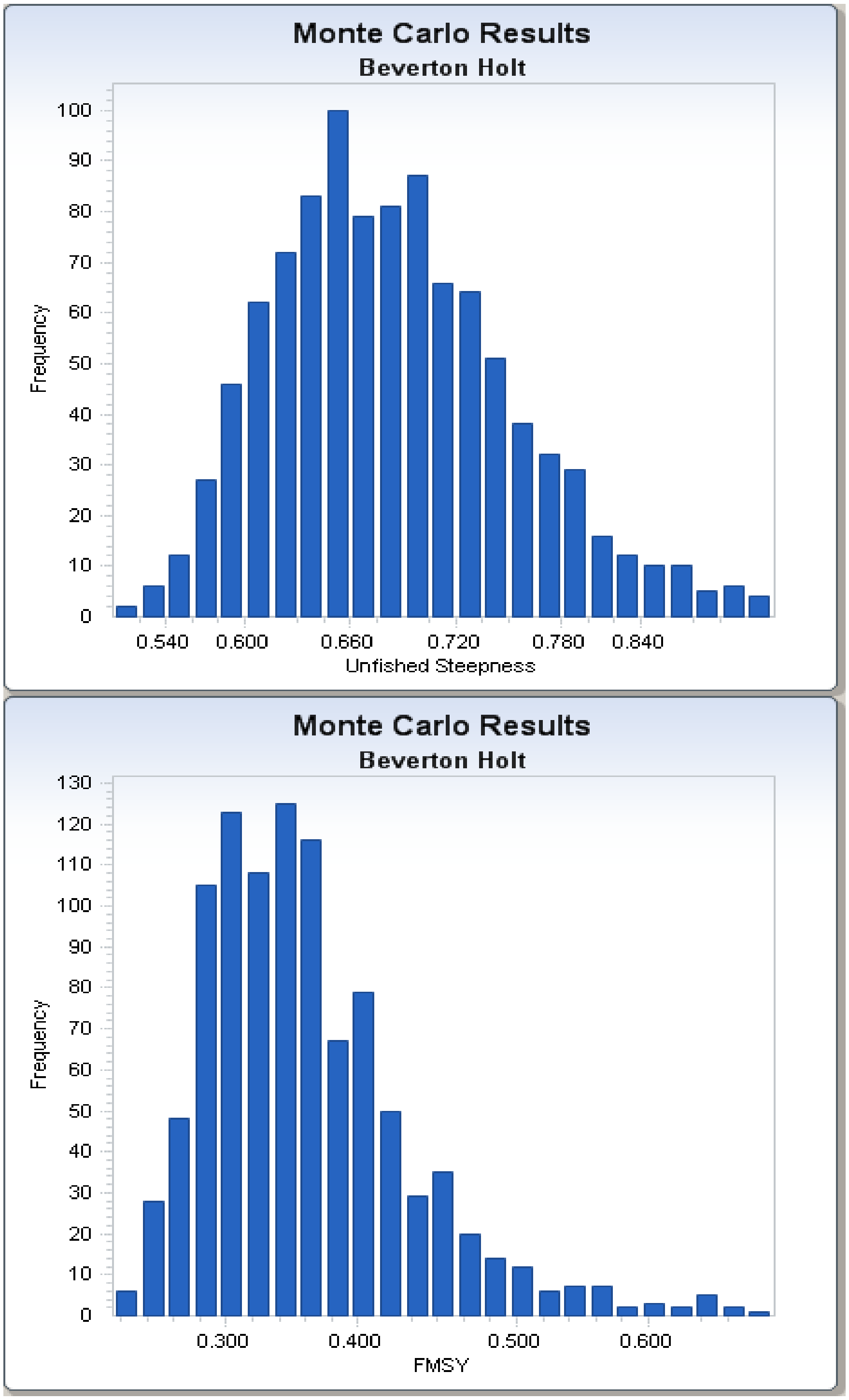


Figure A73. MCMC Results for the ASAP CAT10 stock-recruitment model with prior on steepness (h = 0.8; SE = 0.09).

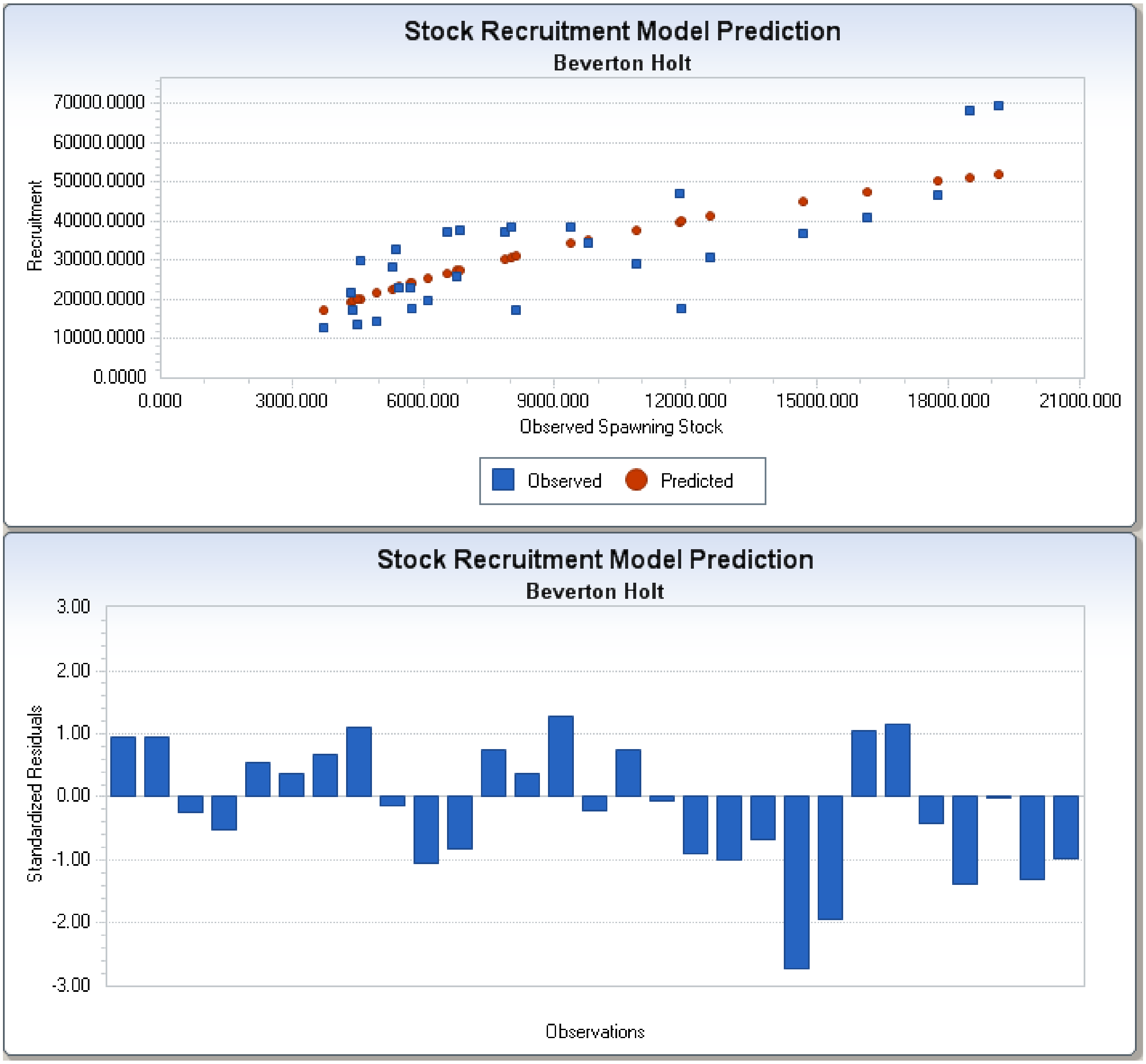


Figure A74. Stock-recruitment model fit with no priors for the ASAP STEPM M=0.3 model estimates.

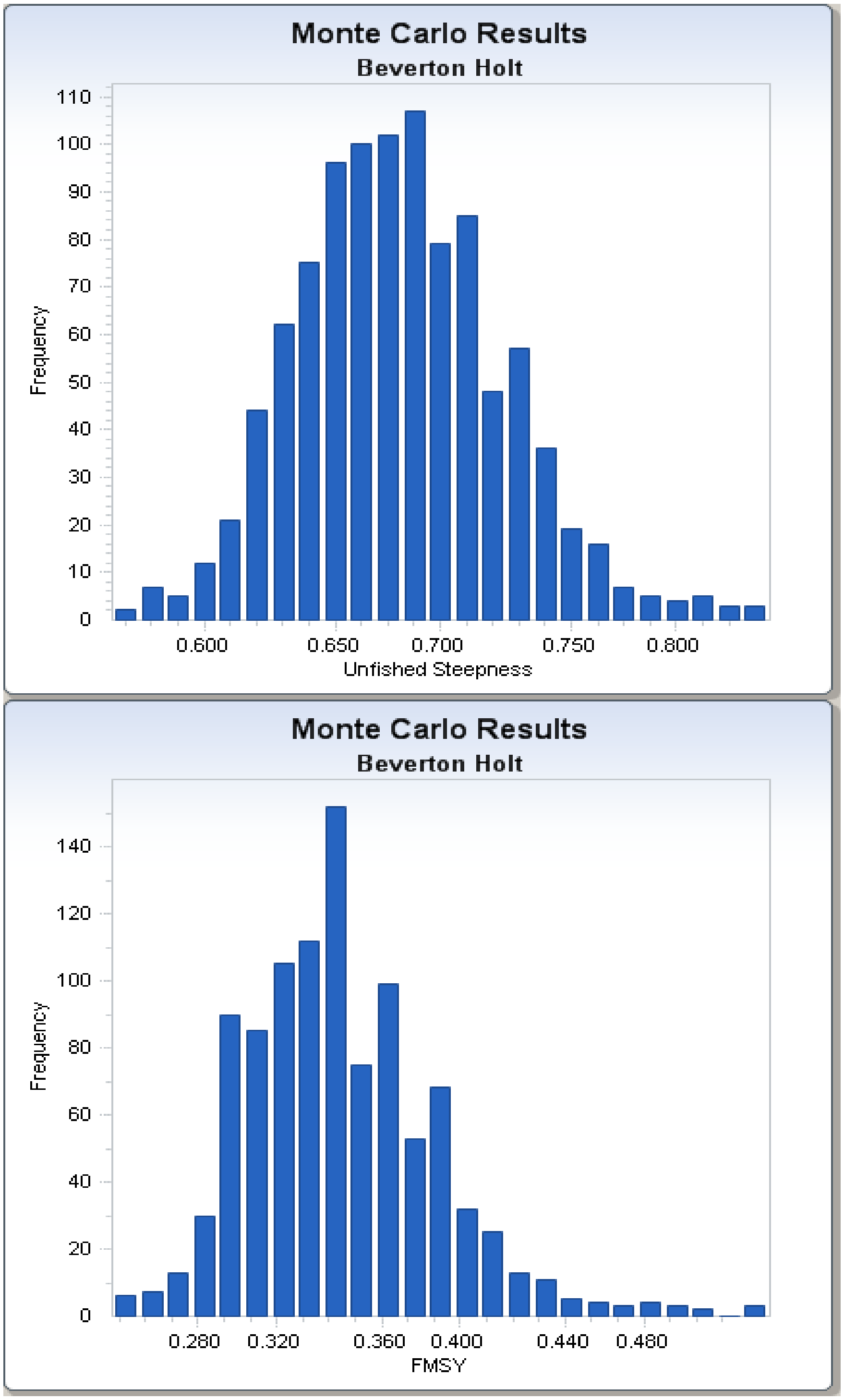
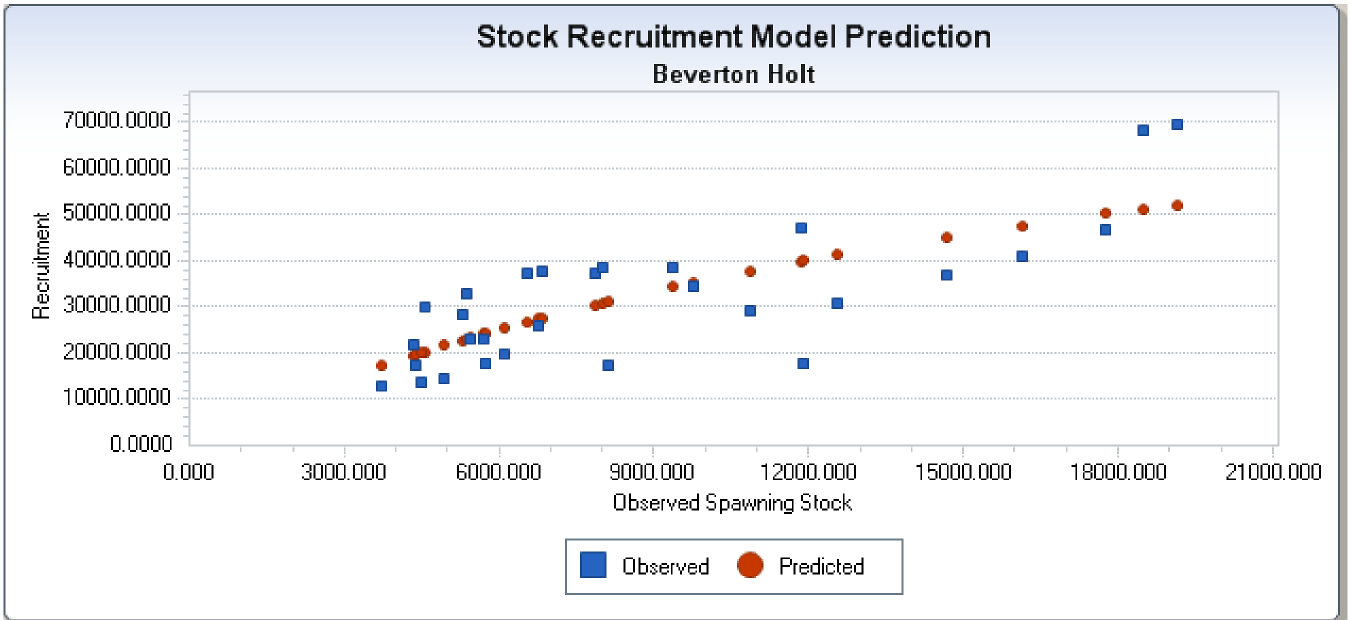


Figure A75. MCMC Results for the ASAP STEPM M = 0.3 stock-recruitment model with no priors.



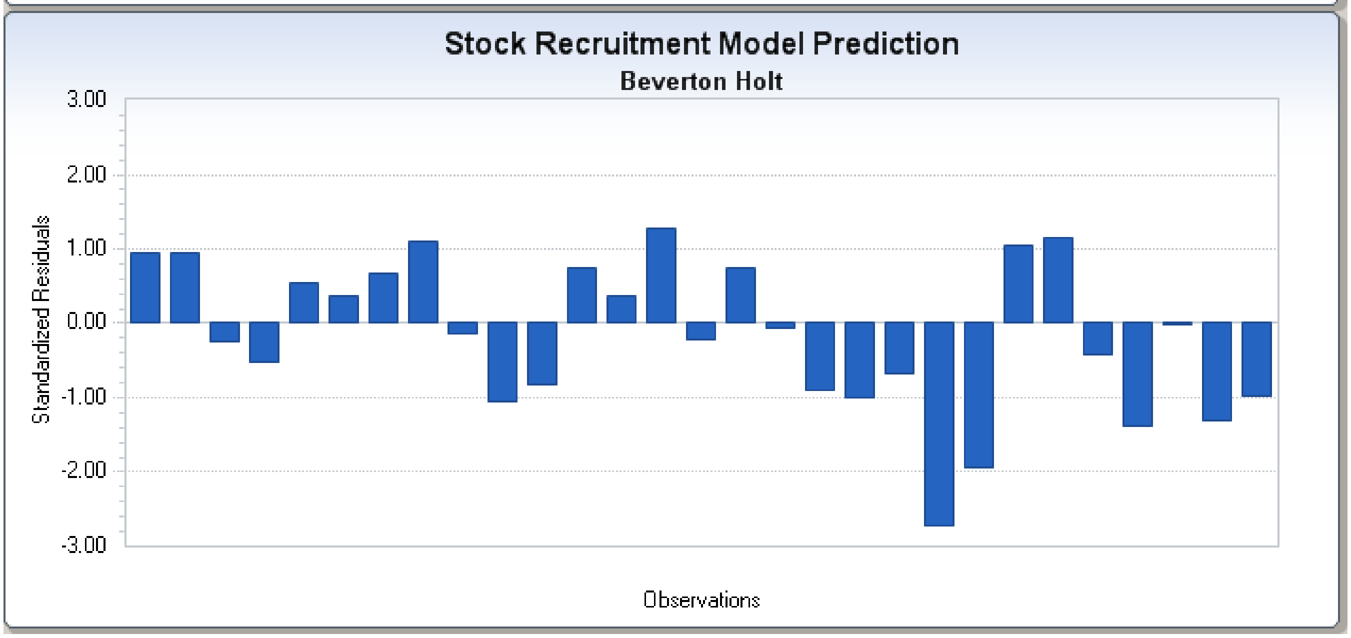


Figure A76. Stock-recruitment model fit with no priors for the ASAP STEPM M = 0.6 model estimates.

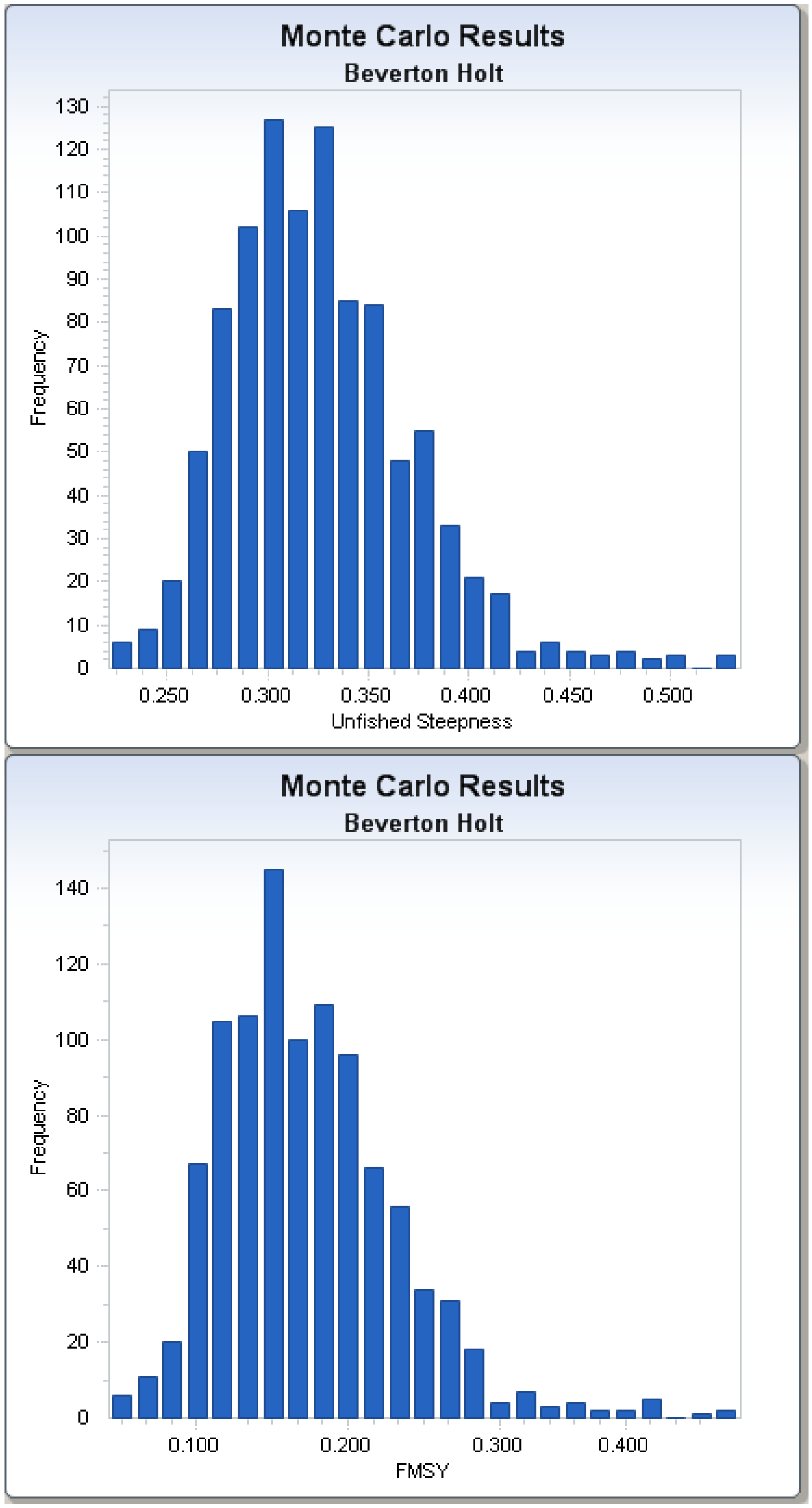


Figure A77. MCMC Results for the ASAP STEPM M=0.6 stock-recruitment model with no priors.

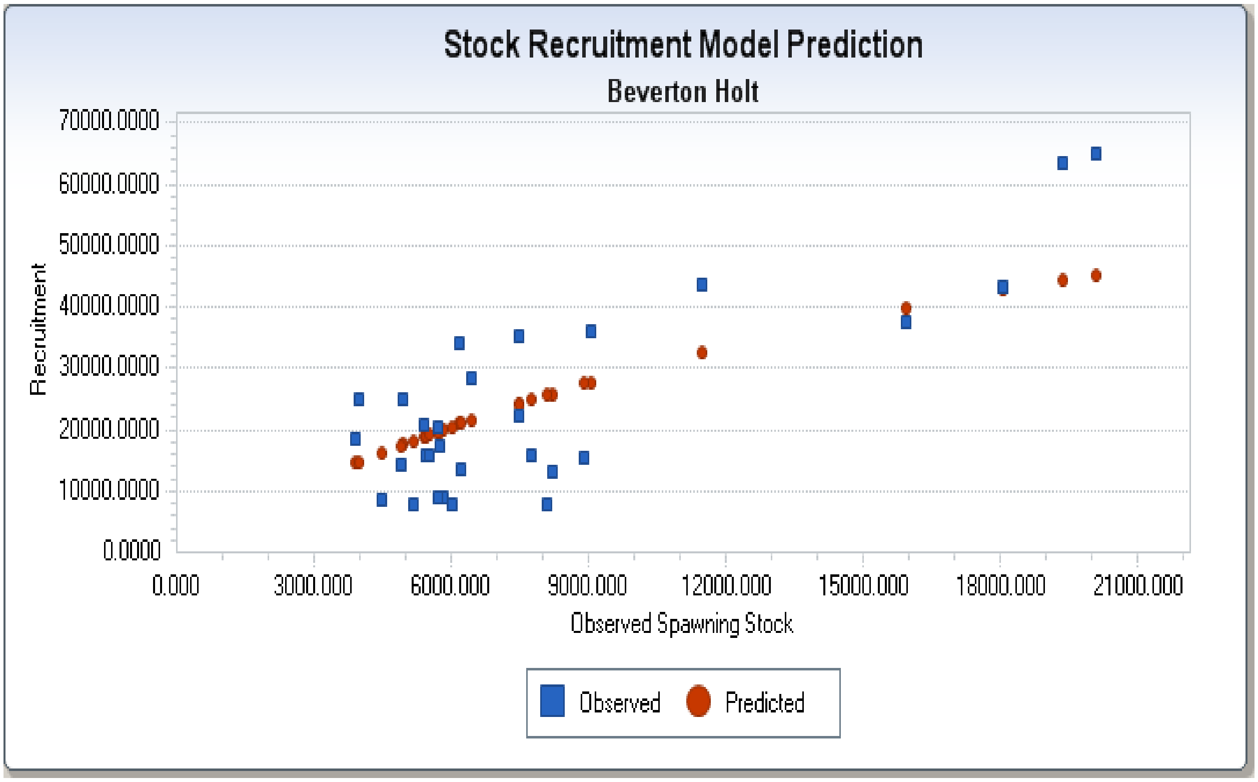


Figure A78. Final stock-recruitment model for SNE/MA winter flounder.

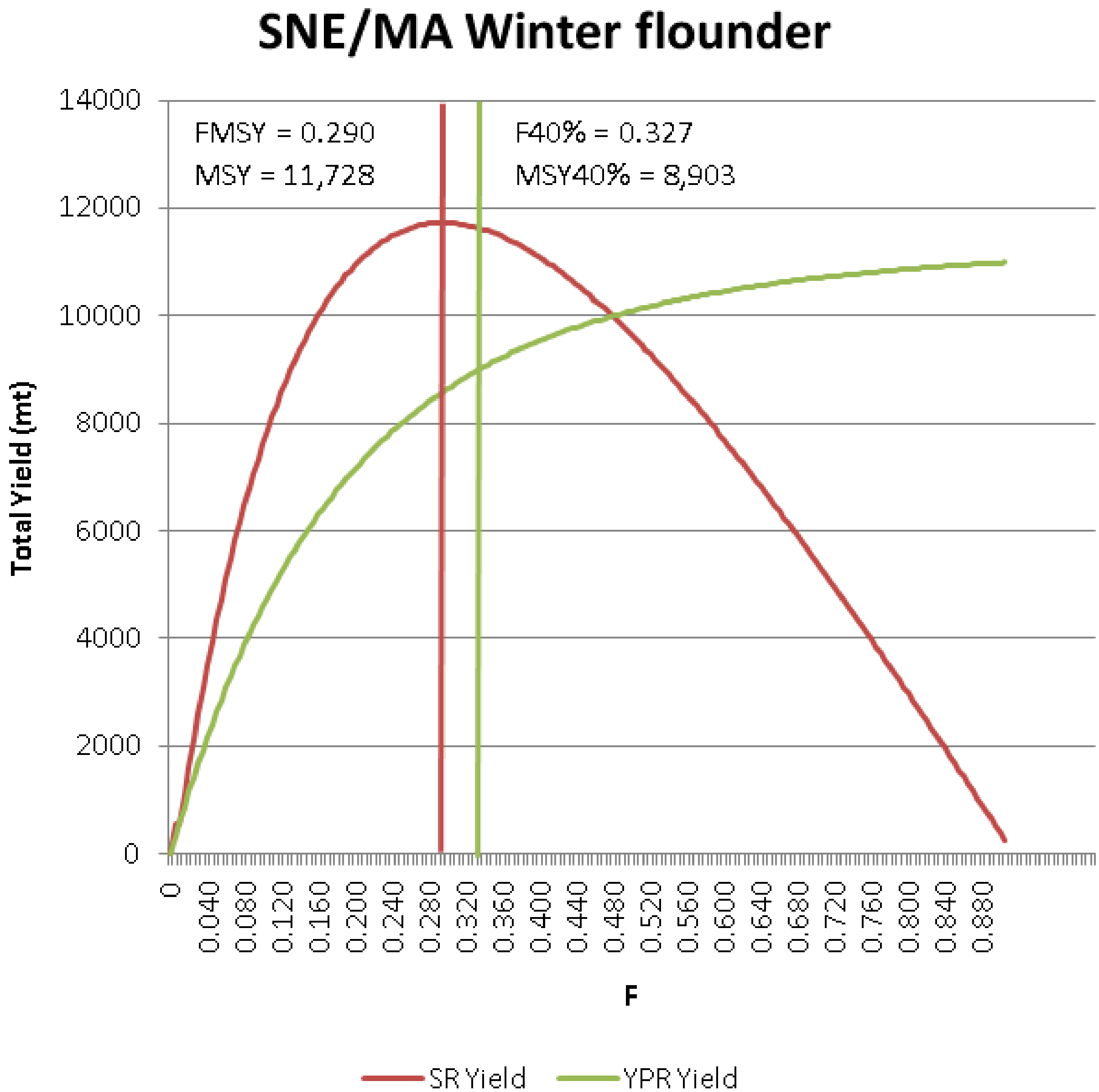


Figure A79. Comparison of fishing mortality versus total yield for stock-recruitment model based BRPs (FMSY, MSY) and yield per recruit model based BRPs (F40%, MSY40%).

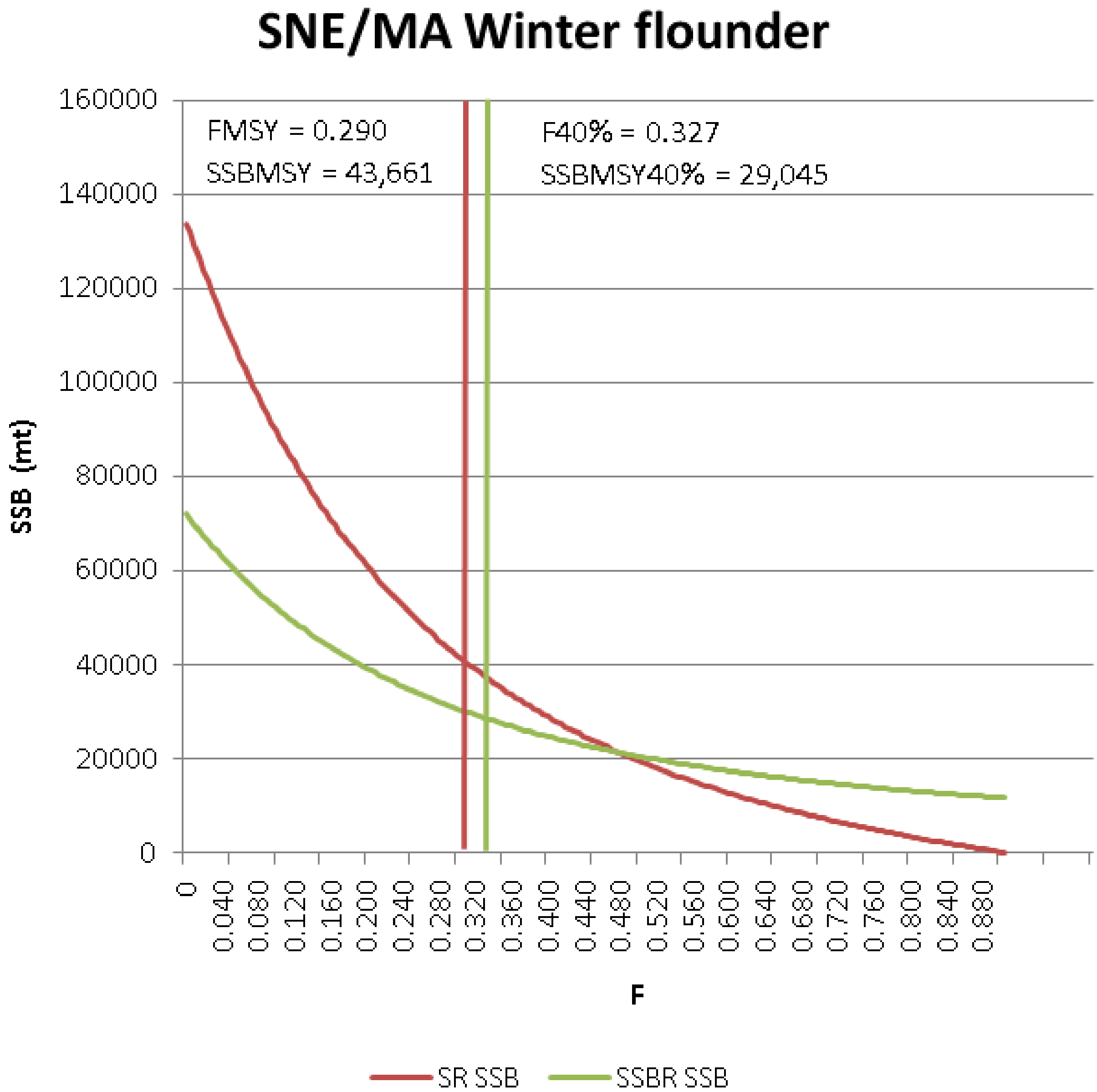


Figure A80. Comparison of fishing mortality versus SSB for stock-recruitment model based BRPs (FMSY, SSBMSY) and yield per recruit model based BRPs (F40%, SSB40%).

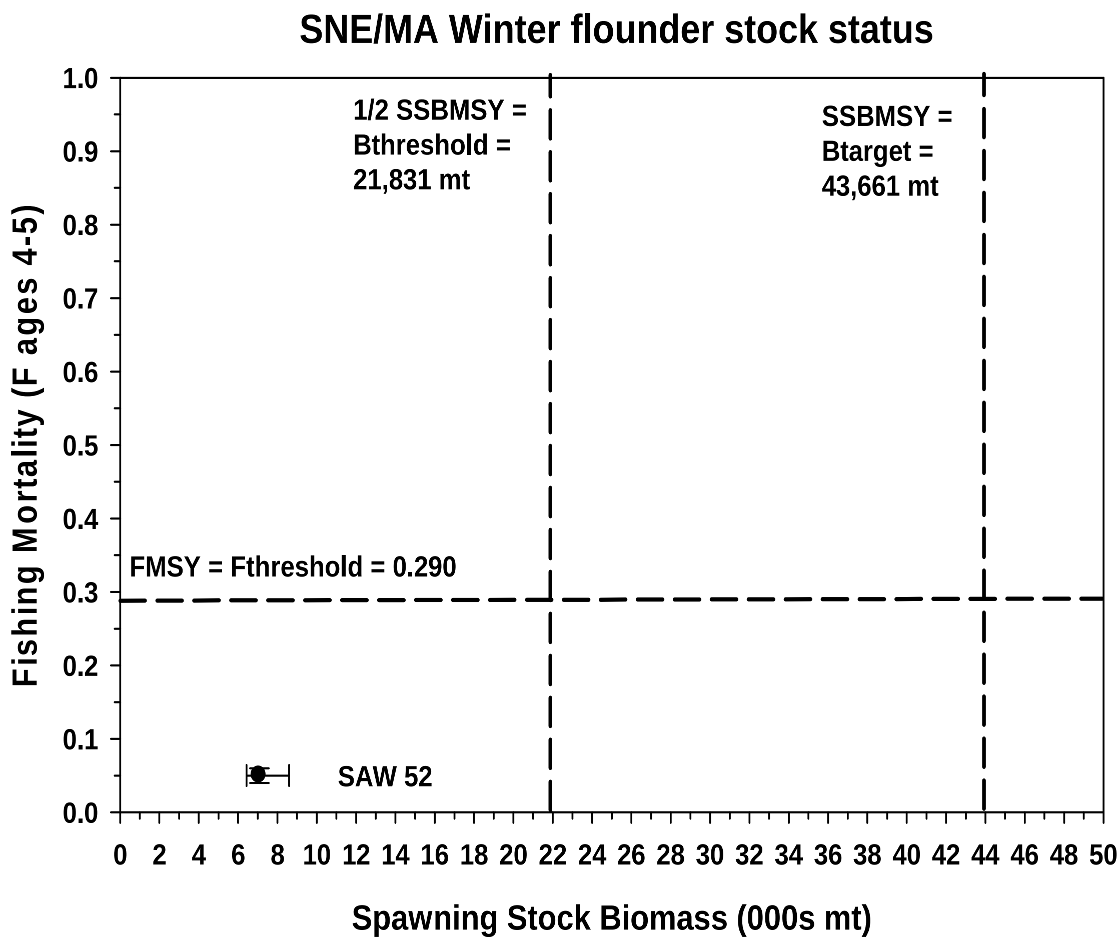


Figure A81. 2011 SAW 52 stock status for 2010 with respect to MSY-based BRPs; error bars are 80% confidence intervals.

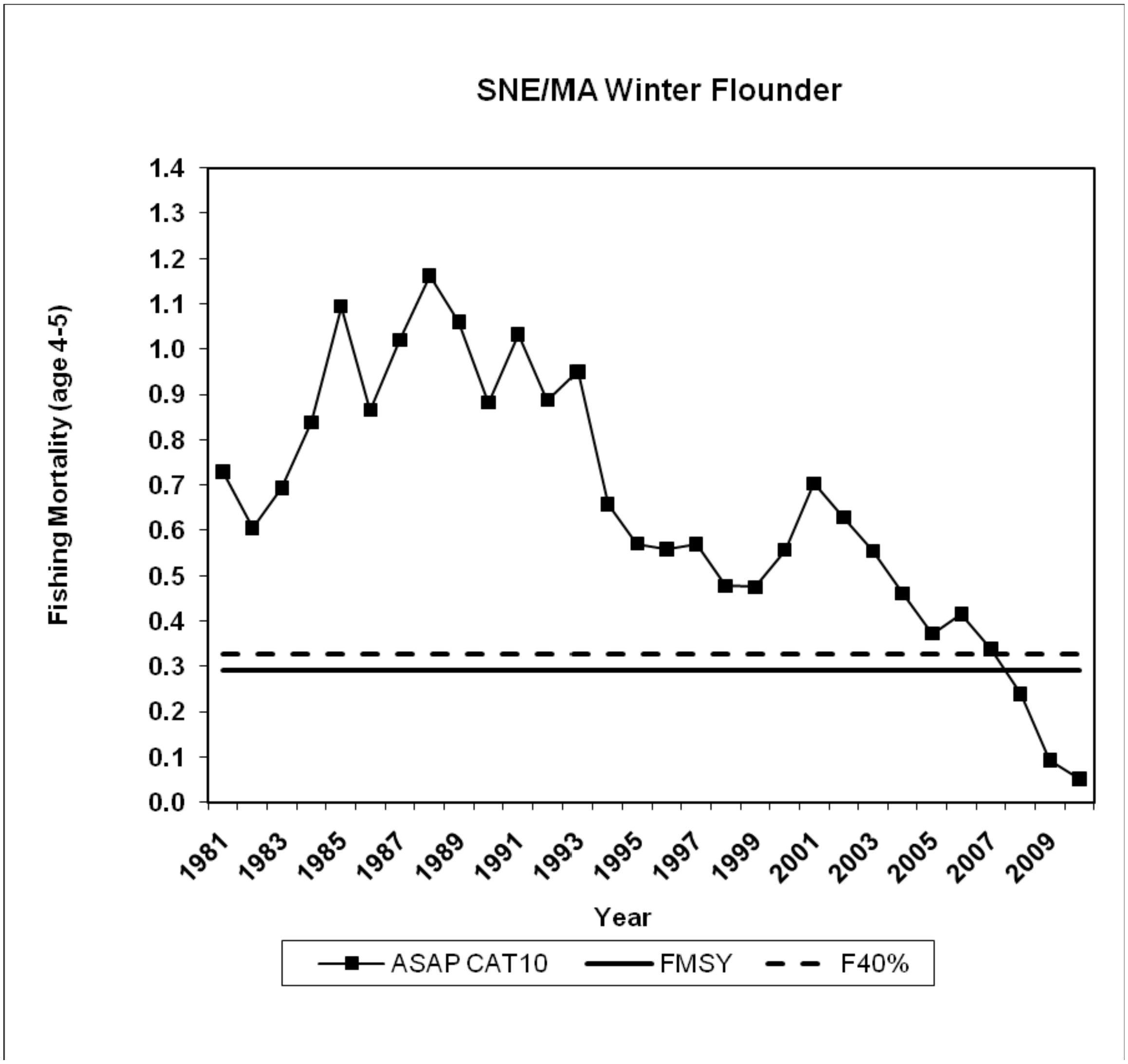


Figure A82. ASAP CAT10 model estimated trend in Fishing Mortality (age 4-5) and associated BRPs for SNE/MA winter flounder.

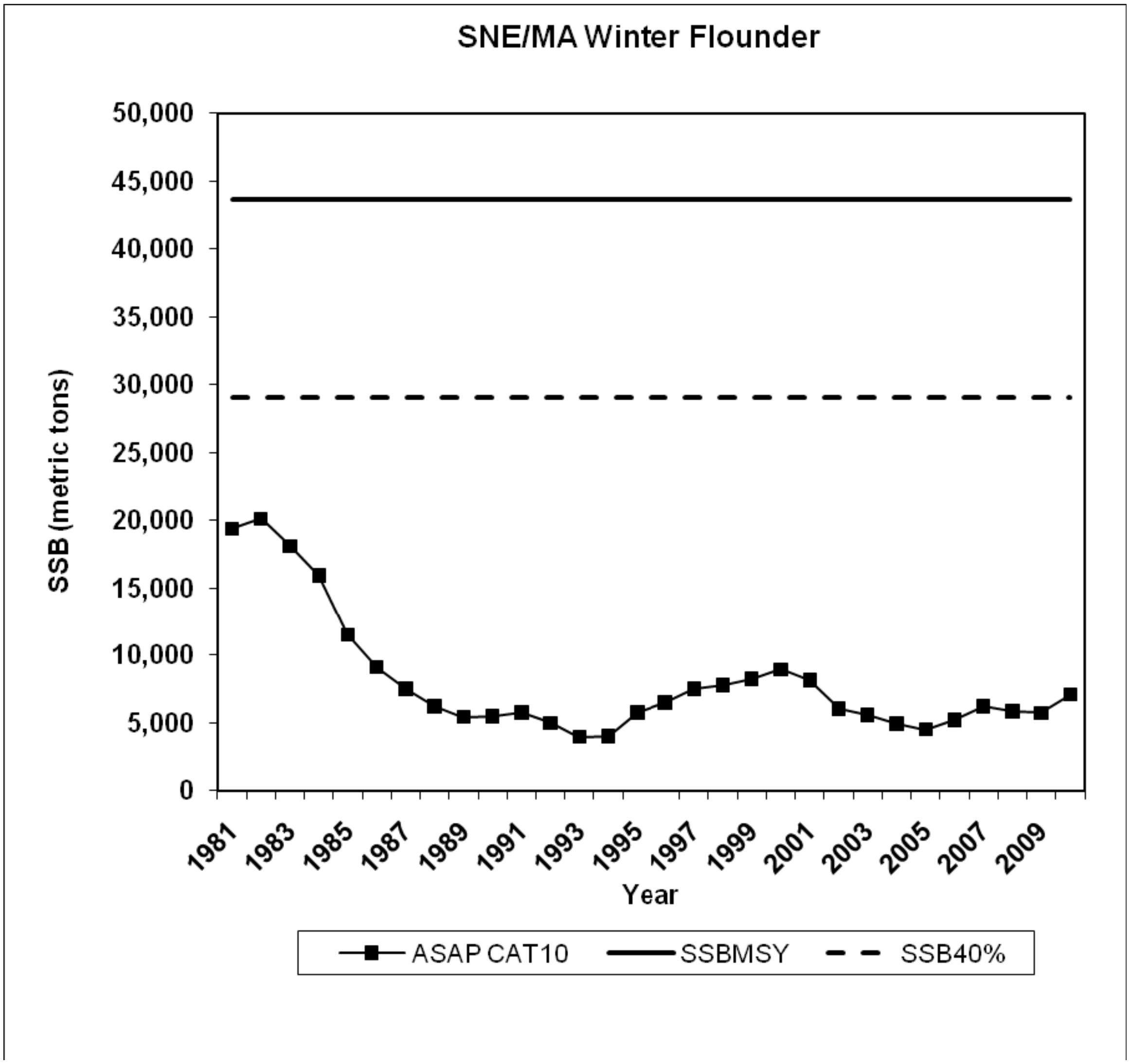


Figure A83. ASAP CAT10 model estimated trend in Spawning Stock Biomass (SSB) and associated BRPs for SNE/MA winter flounder.

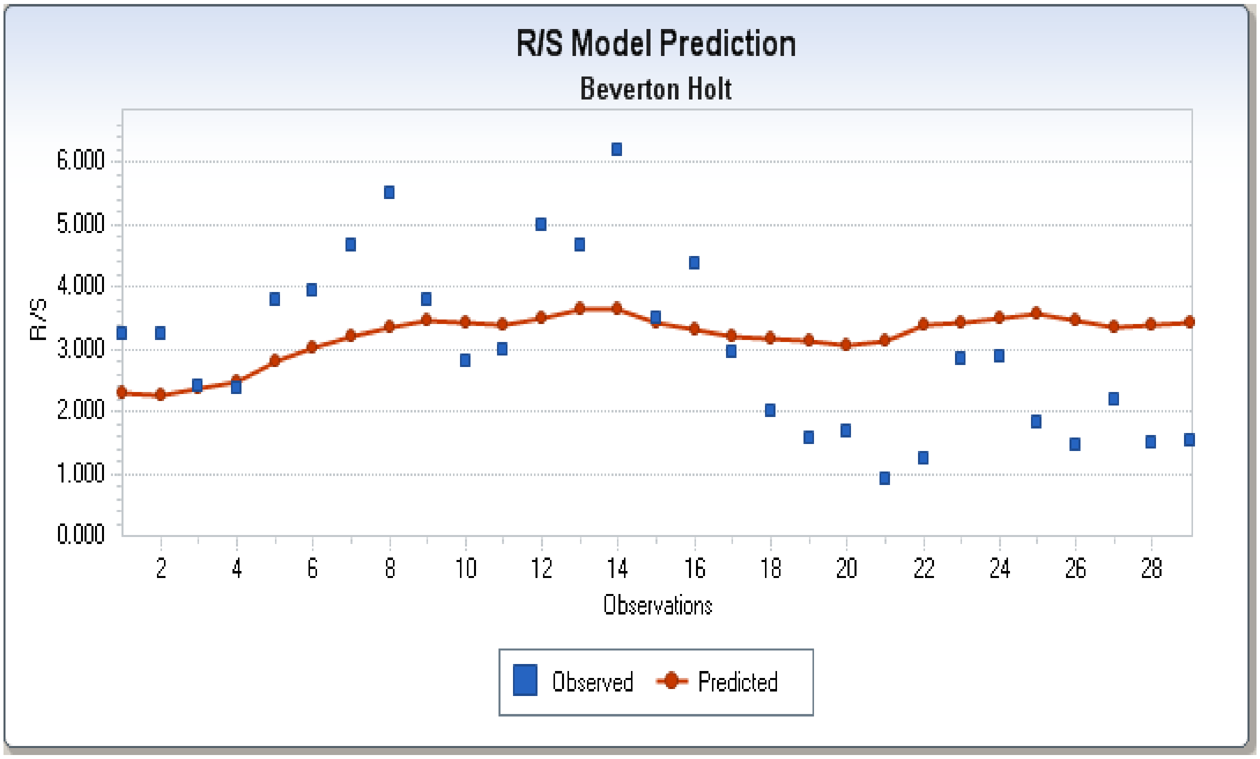


Figure A84. Time series trend in Recruits per Spawner (R/S) for SNE/MA winter flounder; most recent years are on the right side of the plot.

B. Stock Assessment of Georges Bank (GBK) Winter Flounder for 2011

Executive Summary

Term of Reference 1: ***Estimate catch from all sources, including landings and discards. Characterize the uncertainty in these sources of data.***

Catches were dominated by landings from the U.S. groundfish bottom trawl fleet during 1964-2010. Since 1964, total landings have been predominately from the U.S groundfish trawl fishery, but landings have also been reported for the Canadian groundfish trawl fisheries, as bycatch in the haddock and cod fisheries. Total landings, mainly from the U.S. and USSR fleets, increased during 1965-1972 to a time series peak of 4,509 mt. During 1970-1993, Canadian landings generally comprised a low percentage (1-2 %) of the total landings, but thereafter increased from 6% in 1994 to a peak of 24 % in 2001 then declined to low levels since then.

Total landings increased during 1964-1972, reaching a peak of 4,509 mt in 1972, then declined to1,892 mt in 1976. A sustained period of high landings occurred during 1977-1984, ranging from 3,061-4,009 mt. After 1984, landings gradually declined to the lowest level in the time series, 783 mt in 1995, but then increased again to 3,139 mt in 2003. Thereafter, landings declined rapidly and reached the second lowest level on record in 2007 (807 mt). During the time period included in the stock assessment model, 1982-2010, total landings averaged 1,950 mt and were slightly below this average in 2009 (1,670 mt) and 2010 (1,297 mt).

During the assessment period, 1982-2010, discards of winter flounder on Georges Bank were higher in the U.S. fisheries prior to 1991 (i.e., primarily from the large mesh (≥ 5.5 in. codend mesh size) fleet during 1964-1975 and the scallop dredge fleet during 1976-2010) and were higher in the Canadian scallop dredge fishery thereafter. Discards of winter flounder by the Canadian groundfish trawl fleet were not available. Total discards were much higher during 1982-1991, than thereafter, but total discards slowly increased between 1995 and 2010. Total discards averaged 15% of the total landings during 1982-2010.

Catches increased during 1964-1972, reaching a peak of 4,608 mt in 1972, but then declined to 2,034 mt in 1976. Catches subsequently increased to 4,290 mt in 1981 then gradually declined to a time series low of 842 mt in 1995. Catches increased to 3,328 mt in 2003 then declined to 1,039 mt in 2007, followed by a slight increase to 2,013 mt in 2009. Total catch in 2010 was 1,544 mt.

Similar to the most recent assessment, in 2008, the stock was assessed using an ADAPT VPA model. Components of the catch-at-age (CAA) consisted of the combined U.S. and Canadian landings-at-age and discards-at-age for the U.S. large-mesh and small-mesh bottom trawl fleets plus the U.S. and Canadian scallop dredge fleets, during 1982-2010, for ages 1-7+. During 1982-1984, the CAA contained a broad range of ages, but was dominated by ages 2-5 and had the highest numbers of fish aged 6 and older. The CAA changed from this more stable age composition to one dominated by ages 2-4, during 1985-1996. During 2000-2005, the catch composition changed back to a predominance of age 3-5 fish and contained more older fish (ages 6 and older), but at the higher levels observed during 1980-1984. The catches were dominated by age 2-4 fish during 2008-2010 as the 2006 year class was harvested by the fishery.
Mean weights-at-age in the catch remained relatively stable during 1985-1996 across most ages, but then declined to a lower level during 1997-2001, for ages 3-5 possibly due, in part, to poor sampling of large fish during part of this time period (Figure B17, Table B16). Mean weights-at-age reached their highest

levels during 2003-2007, but then declined through 2010 to some of their lowest levels since 1982.

Term of Reference 2: ***Present survey data being considered and/or used in the assessment (e.g., regional indices of abundance, recruitment, state and other surveys, age-length data, etc.). Characterize uncertainty in these sources of data.***

Minimum population sizes estimated from the Canadian and U.S. spring surveys and the U.S. fall surveys, for ages 1-7+ during 1982-2010,were included in the VPA model. A fourth order polynomial model was fit to the U.S. survey data for the Georges Bank stock region and was used to calculate the factors-at-length that were used to convert the 2009-2010 Bigelow survey indices to Albatross units for use in VPA model calibration. CVs-at-age for the tuning indices were highest for the Canadian spring surveys (ranging from 0.21 to 0.41), followed by the U.S. fall survey indices (ranging from 0.16 to 0.28) and U.S. spring indices (ranging from 0.13 to 0.24).

Despite considerable inter-annual variability, the NEFSC fall survey relative abundance indices show an increasing trend during the 1970's, followed by a declining trend during the 1980s to a time series low in 1991. Thereafter, relative abundance increased through 2001 then declined to a level below the 1963-2009 median during 2005-2007. In 2009, fall relative abundance reached the second highest point in the time series, but declined drastically in 2010 to a level slightly below the time series median. Trends in the NEFSC spring survey relative abundance indices exhibited more inter-annual variability, but were similar to the fall survey time series after 1982. NEFSC spring survey abundance indices were at record low levels during 2004-2007. The second highest abundance index of the time series occurred in 2008. However, most of the fish were caught at two consecutively sampled stations and relative abundance declined severely the following year and was at the time series median in 2010. Relative abundance trends in the Canadian survey were similar to those in the NEFSC spring survey during most years but were of greater magnitude during blocks of years (1988-1990 and 1993-1997). Similar to relative abundance indices from the NEFSC spring surveys, indices from the Canadian surveys were at the lowest levels observed during 2005-2007 but then declined to well-below the time series median in 2009 and 2010.

Although the survey numbersat-age were highly variable, large cohorts appeared to track through the numbers-at-age matrices, for the NEFSC surveys, for the 1980, 1987, 1994, 1998-2001, and 2006 cohorts. Age truncation occurred between 1983 and 1997, during which time the population was dominated by four age groups rather than seven or more. During 1997-2004, the age structure improved but has since become truncated again. Both the U.S. and Canadian spring surveys show reduced numbers of age 1-3 fish (and age 4 fish in the CA surveys) during 2000-2007. The Canadian spring survey did not show the same magnitudinal increase in ages 1-6 fish that was evident in the NEFSC spring surveys during 2008-2010.

Term of Reference 3: ***Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series (integrating results from TOR-5), and estimate their uncertainty. Include area-swept biomass estimates. Investigate if implied survey gear or catchability estimates are reasonable. Include a historical retrospective analysis to allow a comparison with previous assessment results.***

The final VPA model differed from the 2008 VPA model because M was increased from 0.2 to 0.3, discards from the Canadian scallop dredge fleet were added to the catch-at-age, and a new maturity schedule was used. Similar to the 2008 GARM assessment results, very mild retrospective patterns were present for terminal years 2001-2009. However, a flip in terminal year estimates of fishing mortality (overestimation during 2006-2009 and underestimation during 2002-2005) and spawning stock biomass (underestimation during 2006-2009 and overestimation during 2002-2005) occurred. There was no retrospective pattern for terminal year age 1 recruitment, but the estimates were highly variable Residuals patterns were evident for a number of ages within each of the three sets of VPA calibration indices.

VPA estimates of survey catchability increased with age for all three surveys. Catchabilities were higher for the NEFSC fall surveys than the NEFSC spring surveys (e.g., q = 0.20 and 0.28 for age 6, respectively), but qs-at-age between the two surveys were not significantly different. Catchabilities for the Canadian spring surveys can be compared across ages but not between surveys because the vessels and gear were different. The catchabilities of ages 1-3 fish were significantly lower than for ages 5-7+ fish.

Fishing mortality rates were highest during 1984-1993, ranging between 0.57 and 1.17, but then declined to levels ranging between 0.31 and 0.51 during 1994-1998. Fishing mortality rates were low (0.26-0.27) during 1999 and 2000, then increased rapidly to 0.85 in 2003, followed by a rapid decline to the second lowest level in the time series (0.20) in 2006. Fishing mortality increased slightly during 2007-2009, but then declined to 0.15 in 2010.

SSB declined rapidly from a time series peak of 17,380 mt in 1982 to 6,256 mt in 1985, then increased slightly through 1987 to 8,082 mt. After 1987, SSB declined again to a time series low of 3,424 mt in 1995. SSB subsequently increased to 13,790 mt in 2000, but then declined to 5,305 mt in 2005. Thereafter, SSB increased and totaled 9,703 mt in 2010.

Trends in age 1 recruitment indicated several periods of rise-and-fall. Recruitment increased from 8.3 million fish in 1983 to a time series peak of 26.3 million fish in 1988, and then declined to 5.2 million fish in 1993. Recruitment increased again to fairly high levels during 1995-1999 (16.2-22.8 million fish) then declined to the second lowest level on record (5.5 million fish) in 2004. Recruitment increased to 18.8 million fish in 2008, but then declined to the lowest level in 2009 (4.0 million fish). Recruitment increased to a very high level (22.5 million fish) in 2010, then declined again in 2011 to near the 2009 level. The 2011 estimate is uncertain because it is based solely on the geometric mean of recruitment during 2003-2009.

Term of Reference 4: ***Perform a sensitivity analysis which examines the impact of allocation of catch to stock areas on model performance (in TOR-3).***

The interpretation of TOR4, by the Southern Demersal Working Group (SDWG), was that the variance of the commercial landings due to the area-allocation scheme (for 1995 and onward) should be used as the basis for estimating the magnitude of landings that might be lost or gained for the stock-specific assessments, and that the assessment models should be run with such potential biases incorporated in order to evaluate their effects on estimates of F, SSB, and R.

For the GB winter flounder stock, total landings for 1995-2010 have a calculated Proportional Standard Error (PSE; due to the aforementioned commercial landings area-allocation procedure) ranging from 0.7% to 1.3%. The total discard PSEs during 1995-2010 ranged from 1% to 56%. Because the PSEs for the landings are low, and the landings accounted for 69-94% of the total catch during 1982-2010, the total catch-weighted annual PSEs ranged from 1.2% to 8.2% and averaged 3.9% (unweighted) for the 1982-2010 time series.

The SDWG developed an exercise using the 2008 GARM assessment data and VPA model in an initial response to TOR4 (Terceiro MS 2011) and concluded that the application of a annually varying unidirectional "bias-correction" provides stock size estimates and BRPs that scale either up or down by about the same average magnitude as the landings gain or loss.

Since the initial exercise of SDWG WP3, the SDWG concluded that the calculated variance of the area-allocated commercial landings likely underestimates the true error. More work was done to estimate the error in the commercial landings due to misreporting of commercial landings to statistical area at allocation level "A" reporting level in mandatory Vessel Trip Reports (Palmer and Wigley MS 2011). The perceived under-reporting of statistical areas in the VTR data led to minor (< 5%) differences in the overall species landings allocations. Therefore, the SDWG elected to an additional 5% PSE to the PSE values of the GB total landings during 1995-2010. This increased the 1995-2010 average landings PSE from 0.9% to 5.7%, and increased the average 1982-2010 catch PSE from 4.0% to 6.2%, with a range of 2.7% in 1983 to 13.7% in 2010.

The catch in the final assessment model was increased/decreased by the annually varying catch PSEs and models were re-run to provide an additional measure of the uncertainty in assessment estimates. As noted in SDWG WP3, the application of a annually varying "bias-correction" in one direction in such an exercise provides stock size estimates that scale up or down by about the same average magnitude as the gain or loss. For the final VPA model results, fishing mortality did not change, on average (out to three decimal places), and the range in 2010 F was 0.154 to 0.162. SSB changed by – 1.0% and +7.9%, on average, and the range in 2010 SSB was 9,636 mt - 10,504 mt.

Term of Reference 5: ***Examine the effects of incorporating environmental factors in models of population dynamics (e.g., spring water temperatures in an environmentally-explicit stock recruitment function).***

The conclusion from the analysis was that recruitment in the coastal stocks of winter flounder (GOM and SNE-MA) were linked to air temperatures during winter, when spawning occurs, but there was no evidence for an air temperature effect on recruitment in the Georges Bank stock; the environmentally-explicit models (which also included a Gulf Stream index) did not provide a better fit compared to the standard stock recruitment model. The Georges Bank stock experiences water temperatures that are affected by both local air temperatures and more importantly, large-scale advective supply of relative cold, fresh water associated with the Labrador Current. Examining other environmental variables which may affect recruitment in the Georges Bank stock (e.g., hydrographic circulation patterns on Georges Bank in relation to larval abundance) is listed below as a future research recommendation.

Term of Reference 6: ***State the existing stock status definitions for "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, and F_{MSY}) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.***

The specification of FMSY and BMSY-based reference points relies on a stock-recruitment relationship. As a result, the 2008 GARM Biological Reference Point Review Panel (NEFSC 2008) concluded that MSY-based BRPs should be adopted when the stock-recruitment relationship is informative, and if not, then the Panel recommended the use of F40%MSP as a proxy for FMSY, similar to the previous recommendation from a separate BRP Working Group for many of the groundfish stocks (NEFSC 2002a), and a BMSY proxy computed using a non-parametric, empirical approach.

For Georges Bank winter flounder, the 2008 GARM BRP Review Panel concluded that the Beverton-Holt stock-recruitment model (Beverton and Holt 1957) fit, using data from a VPA, did not provide feasible results either without a prior (*h*=1) or with a prior (the fit was highly dependent on the assumed prior on unfished recruitment, R_0). Thus, the Panel recommended that the non-parametric empirical approach be used to estimate biological reference points based on: 1) the final VPA model results, 2) the estimate of F40%MSP as a proxy for F_{MSY} (derived using the most recent five-year average of fishery selectivity and weights-at-age and the maturity-at-age time series average), and 3) a long-term (100 year) stochastic projection using the cumulative distribution function of observed recruitment (1983-2007 recruitment at age 1, the 1982-2006 year classes) to estimate MSY and SSBMSY. The existing biomass target is SSBMSY at 40% MSP (= 16,000 mt) and the minimum biomass threshold is 50% of the target (= 8,000 mt). The fishing mortality threshold is an F40%MSP (= 0.26). Amendment 16 defines the fishing mortality target as the mortality associated with the Annual Catch Limit (ACL).

Two sets of candidate BRPs (i.e., FMSY and SSBMSY versus F40% and SSB40%) were brought forward from the current assessment for review by the SARC because the SDWG could not reach consensus on whether the stock-recruit relationship from the Beverton-Holt model was informative, and consequently, whether FMSY was well-estimated. However, the SARC had concerns about the prior on unfished steepness and the fact that the stock-recruitment data for the Georges Bank stock was less informative than the SNE/MA data for predicting recruitment at low spawner levels, making direct estimation of the spawner-recruit relationship difficult without external information. The SARC also concluded that steepness values should be similar between winter flounder stocks. Therefore, the steepness log-likelihood profiles of the two stocks were used in selecting fixed values for steepness with which to estimate FMSY for each stock. Fixed steepness values of 0.61 and 0.78 were selected for the SNE/MA and Georges Bank stocks, respectively. Precision estimates for the resulting FMSY reference point estimates were not possible due to the fixed for steepness. Candidate BRPs estimated for the Georges Bank winter flounder stock which were used to determine 2010 stock status were: FMSY (Fthreshold) = 0.42; SSBMSY (Btarget) = 11,800 mt; ½ SSBMSY (Bthreshold) = 5,900 mt and MSY = 4,400 mt.

Term of Reference 7: ***Evaluate stock status (overfished and overfishing) with respect to the "new" BRPs (from TOR 6), and with respect to the existing BRPs (from a previous accepted peer review) whose values have been updated.***

During 2010, the Georges Bank winter flounder stock was not overfished and overfishing was not occurring. The fishing mortality rate in 2010 (= 0.15) was below FMSY (= 0.42) and spawning stock biomass in 2010 (= 9,703 mt) was above the SSB_{MSY} threshold (= 5,900 mt). In the current assessment, the assumed value for M was increased from 0.2 to 0.3. As a result, the SDWG concluded that a comparison of the 2010 F and SSB estimates from the current assessment with the existing reference points (estimated assuming an M of 0.2) was not appropriate.

Term of Reference 8: ***Develop and apply analytical approaches and data that can be used for conducting single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs) under a set of alternative harvest scenarios. If the stock needs to be rebuilt, take that into account in these projections.***

a. Provide numerical short-term projections (3-5 yrs, or through the end of the rebuilding period, as appropriate). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions about the most important uncertainties in the assessment (e.g., terminal year abundance, variability in recruitment). Take into consideration uncertainties in the assessment and the species biology to describe this stock's vulnerability (see "Appendix to the SAW TORs") to becoming or remaining overfished, and how this could affect the choice of ABC.

Stochastic medium-term projections of future stock status, during 2011-2017, were made based on the current assessment results for the final VPA model and of the final set of candidate BRPs. Maturity-at-age, and mean weights and fishery selectivity patterns-at-age, estimated for the most recent 5 years in the assessment (2006-2010), were used to reflect current conditions in the stock and fishery. The projections assumed that a catch of 2,118 mt (for the FMP Framework 44 fishing year beginning May 1) would be landed as the calendar year catch in 2011. The projections incorporated uncertainty in the current population estimate, via bootstrap replicates, and variability in predicted recruitment. A parametric Beverton-Holt model with log-normal error was used and recruitment variability was generated by randomly sampling from the estimated error distribution of the fitted stock–recruitment model.

The regulations require rebuilding of the Georges Bank stock, with at least 75% probability, by 2017. The projections indicated that rebuilding to SSBMSY (= 11,800 mt) is expected to be achieved with 78% probability in 2012 when fishing at 75% of FMSY (=0.315) with a catch of 2,118 mt in 2011.

Vulnerability, productivity and susceptibility of the Georges Bank winter flounder stock using several methods. Uncertainty was evaluated using model estimates of precision and qualification of other uncertainties. The age-based VPA model and associated MSY reference point evaluations provide a relatively comprehensive and synthetic evaluation of vulnerability that is entirely consistent with stock status determination and projection. With respect to status determination, vulnerability and susceptibility were accounted for with regards to estimation of F in 2010, but precision estimates for F_{MSY} were not possible due to the use of a fixed steepness value in the Beverton-Holt stock-recruit model. Stock vulnerability and susceptibility were also accounted for in the stock rebuilding projection. All components of productivity (reproduction, individual growth, and survival) were also explicitly accounted for in stock status determination and projections. Reproduction was monitored as age-1 recruitment, and projected as a function of SSB (the product of abundance, weight- and maturity-at- age). Individual growth was monitored as empirical size at age, and projected as recent mean size at age. Survival was accounted for based on model estimates of fishing mortality and selectivity as well as assumed natural mortality, which was informed by tagging analysis.

Uncertainties that were not accounted for by assessment and reference point models were evaluated using model diagnostics. Standard model diagnostics (e.g., residual analyses, retrospective analyses) were used for model validation. Vulnerabilities that were not accounted for by assessment and reference point models were evaluated using exploratory modeling, habitat observations and testing the influence of environmental factors on recruitment dynamics. A small portion of the stock (5-17% of the total catch during 2004-2010) is not regulated by the US, yet is susceptible to fishing (i.e., incidental catches) by the Canadian scallop dredge and groundfish bottom trawl fleets. Winter flounder discards in the latter fleet are unknown.

b.Develop plausible hypotheses (e.g., mixing among the three stocks) which might explain any conflicting trends in the data and undertake scenario analyses to evaluate the consequences of these alternate hypotheses on ABC determination.

The SDWG has initiated research pursuing the use of a more complex model (i.e., Stock Synthesis) to maintain separate fishery and survey catch for the three current stock units, while allowing a small amount (a few percent) of exchange between the stock units based on information from historical tagging. However, development of that research has not progressed sufficiently to be made available for peer review at this time.

Term of Reference 9: ***Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.***

A list of progress made on research recommendations from prior assessments and a prioritized list of new research recommendations that would improve the assessment of the Georges Bank winter flounder stock is presented below under TOR 9.

Terms of Reference

1. Estimate catch from all sources including landings and discards. Characterize the uncertainty in these sources of data.

2. Present survey data being considered and/or used in the assessment (e.g., regional indices of abundance, recruitment, state and other surveys, age-length data, etc.). Characterize uncertainty in these sources of data.

3. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series (integrating results from TOR-5), and estimate their uncertainty. Include area-swept biomass estimates. Investigate if implied survey gear or catchability estimates are reasonable. Include a historical retrospective analysis to allow a comparison with previous assessment results.

4. Perform a sensitivity analysis which examines the impact of allocation of catch to stock areas on

model performance (in TOR-3).

5. Examine the effects of incorporating environmental factors in models of population dynamics (e.g., spring water temperatures in an environmentally-explicit stock recruitment function).

6. State the existing stock status definitions for “overfished” and “overfishing”. Then update or redefine biological reference points (BRPs; point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, and F_{MSY}) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the “new” (i.e., updated, redefined, or alternative) BRPs.

7. Evaluate stock status (overfished and overfishing) with respect to the “new” BRPs (from TOR 6), and with respect to the existing BRPs (from a previous accepted peer review) whose values have been updated.

8. Develop and apply analytical approaches and data that can be used for conducting single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs) under a set of alternative harvest scenarios. If the stock needs to be rebuilt, take that into account in these projections.
   a. Provide numerical short-term projections (3-5 yrs, or through the end of the rebuilding period, as appropriate). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions about the most important uncertainties in the assessment (e.g., terminal year abundance, variability in recruitment).
   b. Take into consideration uncertainties in the assessment and the species biology to describe this stock’s vulnerability (see “Appendix to the SAW TORs”) to becoming or remaining overfished, and how this could affect the choice of ABC.
   c. Develop plausible hypotheses (e.g., mixing among the three stocks) which might explain any conflicting trends in the data and undertake scenario analyses to evaluate the consequences of these alternate hypotheses on ABC determination.

9. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

Assessment history

The Georges Bank winter flounder stock was assessed in November, 2001 at SAW/SARC 34 (NEFSC 2002b). The assessment results and biological reference points (BRPs) were based on an ASPIC biomass dynamics model (Prager 1995) which incorporated landings (1964-2000) and biomass indices from the NEFSC autumn (1963-2000) and spring (1968-2001) bottom trawl surveys. Model results indicated a reasonable fit to the input data and that yield has been below surplus production since 1994. Relative estimates of mean biomass (B_t/B_{MSY}) declined sharply during 1977-1994, then increased to B_{MSY} in 2000. Relative fishing mortality rates (F_t/F_{MSY}) were at or below F_{MSY} during1994-2000. During 2000, the stock was not overfished and overfishing was not occurring.

During the 2002 GARM (NEFSC 2002c), stock status was assessed from the results of an updated run of the SAW 34 ASPIC model formulation. Data included in the model were: the NEFSC survey biomass indices for autumn of 1963-2001 and spring of 1968-2002, and total landings during 1964-2001. Fishing mortality rates declined sharply during 1993 and 1999, from 0.71 to 0.14, and were at or below F_{MSY} (= 0.32) during 1995-2001. Average total biomass increased after 1994 and was slightly above B_{MSY} during 2001. There was no retrospective pattern in the ASPIC-derived estimates of fishing mortality rates or total biomass. The biological reference point estimates from the SARC 34 ASPIC model were also recommended for implementation by the 2002 Working Group on Re-estimation of Biological Reference Points for New England Groundfish (NEFSC 2002a). The existing reference points were: F_{MSY} = 0.32, B_{MSY} = 9,400 mt, and MSY = 3,000 mt. The 2002 Working Group concluded that the use of absolute reference point values from the ASPIC model (based on total biomass rather than exploitable biomass) were appropriate because the NEFSC surveys appeared to measure the biomass of the exploitable portion of the stock. The 2001 fishing mortality rate estimate was 0.25 and the 2001 total biomass estimate was 9,805 mt. Therefore, the stock was not overfished and overfishing was not occurring in 2001.

The stock was assessed next in September 2005 during GARM 2 (NEFSC 2005). The assessment consisted of an updated run of the SARC 34 ASPIC model (Prager 2004) formulation. Input data to the model included landings (1964-2004) and NEFSC fall (1964-2004) and spring (1968-2005, lagged back one year) survey relative biomass indices. ASPIC-based biological reference points are re-estimated each time the model is run and model estimates of relative total biomass (B_t/B_{MSY}) and fishing mortality rates (F_t/F_{MSY}) are more precisely estimated than the absolute values (Prager 1995). Therefore, the 2005 GARM review panel concluded that bias-corrected relative estimates of annual total biomass and fishing mortality rates from the updated ASPIC model run should be compared to relative biological reference points (biomass threshold = 0.5, fishing mortality rate threshold = 1.0) to determine stock status. In 2005, the stock was not overfished, but overfishing was occurring.

For the 2008 GARM (NEFSC 2008), a VPA model was used because of improved biological sampling of the fishery since SARC34, the need to assess changes in the population's truncated age structure, and to avoid the pitfalls associated with the biomass-based ASPIC model. Model inpuat data included: catch - at-age data for ages 1-7+, including initial estimates of discards-at-age, for the U.S. bottom trawl and scallop dredge fleets and U.S. and Canadian landings. At the GARM 3 BRP meeting, the review panel determined the stock-recruitment relationship predicted from a Beverton-Holt model was not reliable. As a result, BRPs were derived based on the empirical cumulative distribution function of age 1 recruitment, for 1982-2007, from the VPA model. A 100-year, stochastic projection was run using an age-structured projection model and assuming a constant harvest scenario of $F_{40\%}$ = 0.26 (estimated from a per-recruit model) to predict the median MSY40% (= 3,500 mt) and SSB40% (=16,000 mt) under equilibrium conditions. The 2007 fishing mortality rate (= 0.28) was above the F_{MSY} proxy (= 0.26), indicating that overfishing was occurring in 2007. The spawning stock biomass in 2007 (= 4,964 mt) was well below the SSB_{MSY} target (8,000 mt), indicating that the stock was also overfished in 2007. The 2007 estimates of average F and SSB did not require adjustments for the mild VPA retrospective pattern because the 2000-2006 average Mohn's rho values for average F and SSB were within the 80% confidence limits of the average F and SSB estimates.

The current assessment is an update of the VPA model formulation from the 2008 GARM (NEFSC 2008), including data for 1982-2010, but with the addition of discards-at-age for the Canadian scallop dredge fleet, an assumed increase in M from 0.2 to 0.3, and a new maturity schedule.

Growth and maturity

Winter flounder in the Gulf of Maine and Southern New England reach a maximum size of around 2.25 kg (5 pounds) and 60 cm. On Georges Bank fish may reach a maximum length of 63.5 cm and weight up to 3.6 kg (8 pounds; Bigelow and Schroeder 1953). An updated compilation and analysis of the NEFSC and MADMF survey growth and maturity data for 1976-2010 indicated the following maximum age and length and von Bertalanffy growth parameters that generally support the current stock identifications (Figure B1):

GOM: N = 16,010 fish, maximum age = 15 (55 cm); maximum length = 61 cm;
$L\infty$ = 46.4 cm, k = 0.2727

GBK: N = 6,311 fish, maximum age = 18 (50 cm), maximum length = 70 cm;
$L\infty$ = 57.9 cm, k = 0.2829

SNE: N = 23,593 fish, maximum age = 16 (51 cm), maximum length = 60 cm;
$L\infty$ = 46.5 cm, k = 0.3184

Previous assessments of SNE-MA winter flounder (NEFSC 1999; NEFSC 2003; NEFSC 2005 and NEFSC 2008) have included maturity schedules derived using data for females from the MA DMF spring surveys and published in O'Brien et al. (1993), who fit probit regression models assuming lognormal error to the maturity at age data to estimate the proportions mature at age.

In response to a SAW 28 research recommendation (NEFSC 1999), the 2002 SAW 36 (NEFSC 2003) examined NEFSC spring trawl survey data for the 1981-2001 period in an attempt to better characterize the maturity characteristics of the SNE/MA winter flounder stock complex. The NEFSC maturity data indicated earlier maturity than the MADMF data, with L50% values ranging from 22-25 cm, rather than from 28-29 cm, and with ~50% maturity for age 2 fish, rather than ~50% maturity for age 3 fish (NEFSC 2003). This trend was confirmed through histological analyses by McBride et al. (MS 2011) which indicated that age 2 fish are likely not mature (also see SDWG WP 13). Therefore, given the results from the SAW 36 comparisons and the histological study, the SDWG concluded that the MADMF spring survey data continue to provide the best macroscopic evaluation of the maturity stages for SNE/MA winter flounder and that 1982-2008 time series of maturity estimates at age should be used for SARC 52 assessment.

Georges Bank winter flounder spawn during March-May, with a peak in April (Smith 1985).The maturity schedule used in the VPA model during the previous stock assessment (NEFSC 2008), shown in the following table, was the time series average during 1982-2007 for females caught during NEFSC spring surveys (which generally occur on Georges Bank during April). Probit regression models assuming lognormal error were fit to the maturity at age data to estimate the proportions mature at age. Given the finding that the NEFSC spring surveys suggest that the age at 50% maturity occurs one year earlier than the A50 computed from the MA DMF surveys and the histological results in the McBride et al. (2010), the SDWG adopted the maturity schedule shown in the table below. The maturity schedule was estimated as a 3-year moving window based on an adjustment of the female maturity-at-age data from the 1981-2010 NEFSC spring surveys (strata 13-23). Based on the female maturity at length data for the 57 Georges Bank fish from the histology study (Figure B2), fish > 30 cm TL were misidentified macroscopically, at sea, as immature fish and fish < 38 cm were misidentified as resting fish. Therefore, immature fish > 30 cm (= 7% of the immature fish during 1981-2010) and resting fish < 38 cm (= 28% of the mature fish during 1981-2010) were deleted prior to fitting the probit regression model. All of the deleted fish were ages 2 and 3. The resulting female A50 values and their 95% confidence intervals are shown in Figure B3.

Age	1	2	3	4	5	6	7+
Stock, assessment period (years included)							
GB, 2008 GARM (1982-2007)	0.08	0.54	0.94	1.00	1.00	1.00	1.00
SNE/MA, current assessment (1982-2008)	0.00	0.08	0.56	0.95	1.00	1.00	1.00
GB, current assessment (1981-2010)	0.00	0.09	0.90	1.00	1.00	1.00	1.00

Instantaneous natural mortality (M)

The SDWG adopted a change in the instantaneous rate of natural mortality (M) for the winter flounder stocks. The value of M previously used in all assessments was 0.2 for all ages and years, and was based on the ICES 3/Tmax "rule-of-thumb" (e.g., see Vetter 1998 and Quinn and Deriso 1999)using observed maximum ages for winter flounder (Tmax) of about 15. The current observed Tmax values for the three stock units are GOM = 15 years, GBK = 18 years, and SNE/MA = 16 years (see previous Growth and Maturity section). The adopted change increases this rate to 0.3 for all stocks, ages and years. Evidence can be found in the literature and current model diagnostics to support the increase.

Literature values of M from tagging studies and life history equations indicate M for winter flounder is likely higher than 0.2. Dickie and McCraken (1955) carried out a tagging study in St. Mary Bay, Nova Scotia, Canada (GOM Stock) and estimated a percentage natural mortality rate to be 30% (M = 0.36). Saila et al. (1965) applied Ricker's equilibrium yield equation to winter flounder from Rhode Island waters (Tmax = 12) and using F values from Berry et al. (1965) calculated M to be 0.36. Poole (1969) analyzed tagging data from New York waters from five different years and estimated values for M of 0.54 (1937), 0.33 (1938), 0.5 (1964), 0.52 (1965), and 0.52 (1966). Finally, an analysis of tagging data from a large scale study along the coast of Massachusetts provided a percentage natural mortality rate of 27%, or M = 0.32 (Howe and Coates 1975). For this assessment, a re-analysis of the Howe and Coates (1975) tagging data was conducted using a contemporary tagging model to estimate natural mortality (Wood WP 15). The tagging model fit to the data was the instantaneous rates formulation of the Brownie et al. (1985) recovery model (Hoenig et al. 1998). This work provided an M of 0.30 with 95% confidence interval from 0.259 to 0.346.

Values derived from life history equations found in the literature also support a higher estimate of M for winter flounder. Three equations were used along with a maximum age (Tmax) of 16 to derive estimates of M equal to 0.28, 0.26, and 0.19 (the equations from Hoenig 1983, Hewitt and Hoenig 2005, and ICES, respectively). A newly proposed method from Gislason et al. (2010), based on SNE/MA stock mean size at age (Ages 1-16) and von Bertalanffy growth parameters, estimated M to be 0.37 (see text table below).

Values of natural mortality (M) for winter flounder found in the literature and derived using life-history equations.

Study	**Method**	**M**

ICES rule-of-thumb	Equation: 3/Tmax	0.19
Hewitt and Hoenig 2005	Equation: 4.22/Tmax	0.26
Hoenig 1983	Equation: 1.44-0.982*ln(Tmax)	0.28
Howe and Coates 1975	Analysis of Tagging Data	0.32
Wood 2011 (WP15)	Re-analysis of Howe and Coates 1975	0.30
Poole 1969	Analysis of Tagging Data from 1938	0.33
Dickie and McCraken 1955	Analysis of Tagging Data	0.36
Saila et al. 1965	Ricker Equil. Yield Equation and Tmax	0.36
Gislason et al. 2010	Equation: Mean size at age and VBG	0.37
Poole 1969	Analysis of Tagging Data from 1964	0.50
Poole 1969	Analysis of Tagging Data from 1965	0.52
Poole 1969	Analysis of Tagging Data from 1966	0.52
Poole 1969	Analysis of Tagging Data from 1937	0.54

Preliminary assessment population model run diagnostics also, in general, support a higher value for M. Profiles in mean squared residual for ADAPT VPA SNE/MA stock models indicate best fits for M in the range of 0.2 to 0.3. The likelihood profile of initial ASAP SCAA model runs for the SNE/MA stock indicates a best fit for M= 0.6. Model runs from Rademeyer and Butterworth SCAA (ASPM) model (2011) at M equal to 0.2, 0.3, and 0.4 also revealed decreasing negative log-likelihood as M is increased for GOM and SNE/MA stock models (see the following two text tables).

Results of SCAA for the Gulf of Maine winter flounder for each combination of 3 levels of natural mortality (*M*=0.2, 0.3 and 0.4, constant throughout the assessment period) and 3 weightings of the survey CAA likelihood (*w*=0.1, 0.3 and 0.5). The runs with w=0.3 and 0.5 have both commercial and survey selectivities flat at older ages, while the runs with w=0.1 have only the commercial selectivity flat. Displayed values are the negative log-likelihoods of each model.

	M		
Weighting	0.2	0.3	0.4
0.1	-123.2	-126.6	-129.1
0.3	-156.9	-177.2	-196.1
0.5	-255.6	-263.2	-280.8

Results of SCAA for the SNE/MA winter flounder for 3 levels of natural mortality for Base Case 2. Displayed values are the negative log-likelihoods of each model.

	M		
	0.2	0.3	0.4
-LL	-123.2	-126.6	-129.1

The SDWG also considered other evidence that might justify an increase in M for winter flounder. The NEFSC's food habits database (Smith and Link 2010) was examined to identify the major fish predators of winter flounder. These predators include Atlantic cod, sea raven, monkfish (goosefish), spiny dogfish, winter skate and little skate. A preliminary examination was undertaken to determine the prominence of winter flounder in the diets of these predators, across all seasons, years, size classes of predator, sizes of prey, and geographic locales. The overall frequency of occurrence of winter flounder in the stomachs is not a common or high occurrence (see text table below), always less than 0.15%.

Occurrence of winter flounder in their major fish predators

	Number of stomachs	Occurrences of winter flounder	% frequency of occurrence
Spiny dogfish	67,565	27	0.040%
Winter skate	17,708	6	0.034%
Little skate	28,725	6	0.021%
Atlantic cod	20,142	27	0.134%
Sea raven	7,968	10	0.126%
Goosefish	10,742	12	0.112%

Further, the contribution of winter flounder to the diets of these predators species is also notably small (see text table below), usually less than 0.4%.

Contribution of winter flounder to the diets of their major fish predators

	% diet composition, by weight	95% CI
Spiny dogfish	0.2049%	0.10678
Winter skate	0.1454%	0.16008
Little skate	0.0124%	0.01618
Atlantic cod	0.3172%	0.24032
Sea raven	0.8831%	0.78407
Goosefish	0.2492%	0.25947

Understandably, the temptation exists to evaluate these relatively low diet contributions with respect to consumptive removals of winter flounder as compared to winter flounder stock abundance and (relatively low) landings, initially using *ad hoc* or proxy methods. However, just as one would not do so when assessing the status of a stock without a fuller exploration of all the sensitivities, uncertainties and caveats of the appropriate estimators and parameters, the SDWG did not recommend doing so for scoping winter flounder predatory removals at this time. The SDWG also noted that for percentages as low as those observed, when allocated to the three winter flounder stocks and explored seasonally or as a time series, there are going to be large numbers of zeroes and attendant uncertainties and variances that would logically offset any potentially high individual predator total population-level consumption rates. Thus, the SDWG does not provide comment as to the merit of exploring or relative magnitude of the issue, but recommends that the topic should be forwarded as an important research recommendation.

Other sources of increased natural mortality may come from perceived increases in seal populations along the New England coast, which are known to be predators of winter flounder (Ampela 2009). Population size was estimated at 5,600 seals in 1999 (Waring et al. 2009) and a current survey is being conducted to estimate the size of the seal population. However, no time series of seal abundance or consumption of winter flounder is available.

<u>Additional analyses conducted during the SARC</u>

For Georges Bank winter flounder, two sets of candidate BRPs (i.e., FMSY and SSBMSY versus F40% and SSB40%) were brought forward from the current assessment for review by the SARC because the SDWG could not reach consensus on whether the the stock-recruit relationship from the Beverton-Holt model was informative, and consequently, whether FMSY was well-estimated. However, the SARC did not select either set of BRPs. Rather, the SARC concluded that the estimation of a stock-recruit relationship for the Georges Bank stock was difficult without external information and that the use of a steepness prior for Pleuronectids based on Myers et al (1999) was inappropriate. The SARC also concluded that steepness should be similar across all three winter flounder stocks. Therefore, given that the SNE/MA stock-recruit relationship was more informative, the SARC used the log-likelihood steepness profiles of each stock to select a fixed steepness value with which to rerun the Beverton-Holt model to obtain a final estimate of FMSY. The methods and results of the analyses are discussed below under TOR 6.

Term of Reference 1: ***Estimate catch from all sources including landings and discards. Characterize the uncertainty in these sources of data.***

Landings

Statistical Areas used for reporting fishery data for the Georges Bank winter flounder stock include: 522-525, 542, 551-552, and 561-562 (Figure B4). Several different methods have been used to collect the landings, fishing area and effort data. During 1963 through April of 1994, U.S. commercial landings, effort, fishing area, and other fishery-related data were collected and entered into Northeast Region Commercial Fisheries Database (CFDBS) by NMFS port agents, who entered landings data from all dealer purchase receipts and interviewed a subset of captains to obtain information about fishing location and effort (Burns *et al*. 1983). During May of 1994-2003, reporting of landings and other associated trip data was mandatory for dealers issued federal permits to purchase groundfish. The data were collected and entered into the CFDBS by NMFS port agents. Since 2004, the landings and associated trip data have been self-reported, electronically, by federally permitted dealers. Beginning in May of 1994, mandatory reporting of fishing location (Statistical Area) and effort data, gear type, estimated catch, and other trip-based fishing data were self-reported by fishermen on logbooks (i.e., Vessel Trip Reports or VTRs) and the data were entered into the Vessel Trip Report Database. In order to integrate data from the VTR Database with data from the CFDBS, an "allocation" database was created using a trip-based allocation scheme (Wigley et al. 2008a). Landings data are assumed known and originate from the CFDBS. The allocation determines the area fished and effort information reported on the VTR data and joins this information with the landings data from each trip as reported in the CFDBS. Two levels (A and B) represent vessel-oriented data and two levels (C and D) represent fleet-oriented data. Level A comprises audited VTR trips that have not been grouped and for which a one-to-one match exists between the VTR and CFDBS fields which define a trip (i.e., year, month, day and permit). Level B comprises VTR trips from Level A that have been pooled by vessel permit, gear group, main species group, and month. Level C comprises VTR trips from Level A that have been pooled by ton class, port group, gear group, main species group, and calendar quarter. Level D comprises VTR trips from Level A that have been grouped by port group. If a CFDBS trip has a corresponding one-to-one match with a VTR trip, then the area fished and the effort information, if present, is transferred directly onto the CFDBS trip record. "A" level trips correspond to pre-1994 trips for which similar information was obtained from a vessel captain via a port agent interview.

During 1995-2010, 63-78% of the commercial landings were allocated to Statistical Area based on a 1:1 match of trips in the Dealer and Vessel Trip Report Databases (“A” level data), with the majority of the remaining trips allocated at the “B” level for which stratification is based on vessel, month, gear group, and species group basis (Table B1). For the Georges Bank winter flounder landings, the Proportional Standard Error (PSE, reported as a %) due to the allocation of landings to Statistical Area, using Vessel Trip Reports, ranged between 0.7 and 1.3% during 1995-2010 (Table B2).

There are no significant recreational landings of winter flounder from Georges Bank. Commercial landings data were available for 1964-2010. Since 1964, total landings have been predominately from the U.S groundfish trawl fishery, but landings have also been reported for the Canadian groundfish trawl fisheries, as bycatch in the haddock and cod fisheries (Heath Stone pers. comm.). During 1965-1977, landings were also reported by the former USSR; reaching a peak of 1,699 mt in 1972 (Table B3, Figure B5). Canadian landings generally comprised a low percentage (1-2 %) of the total landings until 1994, at which time Canadian landings increased rapidly from 6 % of the total to a peak of 24 % in 2001 (529 mt). The increasing trend in Canadian landings occurred primarily during the second half of the year because since 1994 Canadian groundfish fisheries on Georges Bank have, for the most part, been closed during January-May (Van Eeckhaute and Brodziak 2005). After 2001, Canadian landings declined rapidly to 1.5% in 2007 (12 mt). During 2008-2010, Canadian landings were very low, comprising only 1-3% of the total landings.

Total landings increased during 1964-1972, reaching a peak of 4,509 mt in 1972, then declined to1,892 mt in 1976 (Figure B5, Table B3). A sustained period of high landings occurred during 1977-1984, ranging from 3,061-4,009 mt. After 1984, landings gradually declined to the lowest level in the time series, 783 mt in 1995, but then increased again to 3,139 mt in 2003. Thereafter, landings declined rapidly and reached the second lowest level on record in 2007 (807 mt). During the time period included in the stock assessment model, 1982-2010, total landings averaged 1,950 mt and were slightly below this average in 2009 (1,670 mt) and 2010 (1,297 mt).

Most of the U.S. landings (92-100%) are taken with bottom trawls and most of the remainder is taken by the scallop dredge fleet (Table B4). During most years since 1982, landings taken by the scallop dredge fleet have been less than 1% of the U.S. total. However, a high period of landings by the scallop dredge fleet (4-8% of the total landings) occurred during 1988-1993 and in 2005-2006 (6% and 3%, respectively, of the total landings).

The spatial distribution of winter flounder landings on Georges Bank has largely been affected by complex management regulations. During 1982-1993, prior to the implementation of groundfish Closed Areas I and II (Figure B6), most of the Georges Bank landings of winter flounder were taken in the two northern SAs, 522 and 562. Since 1994, portions of the four SAs where most of the landings occur (522, 525, 561 and 562) have been closed, for the most part, to groundfish bottom trawl fishing (Figure B6). During 1994-2001, most of the landings occurred in SA 522 (37-69%), but then shifted to SA 562 during 2002-2005, where 38-54% of the landings occurred (Figure B7). With implementation of the Eastern (SAs 561 and 562) and Western US/CA Areas (SAs 522 and 525) in May of 2004, which was linked to the establishment of total allowable catches (TACs) for cod, haddock and yellowtail for the US versus CA within their respective EEZs, landings began increasing again in SAs 522 and 525. The shift in where the predominant landings occurred (from the Eastern to the Western U.S./CA Area), after 2004, may have been attributable, in part, to the 2005 requirement to use a haddock separator trawl when fishing in the Eastern U.S./CA Area as well as closures of this Area when cod, haddock or yellowtail quotas are reached. The haddock separator trawl was designed to catch haddock but to reduce incidental catches of other demersal finfish species. During 2006-2009, most of the landings (42-53%) were again taken in SA 522 with most of the remainder taken in SA 525. In 2010, 41% and 38% of the landings were taken in SA 522 and SA 525, respectively (Figure B7).

Discards in U.S. fisheries

Estimates of Georges Bank winter flounder discards in U.S. fisheries, during 1964-2010, are provided for the large mesh bottom trawl fleet (codend mesh size ≥ 5.5 inches), small mesh groundfish fleet (codend mesh size < 5.5 inches), and the sea scallop dredge fleet ("limited permits" only) in Table B5. Discards (mt) from each of the three fleets, during 1989-2010, were estimated based on fisheries observer data (obtained the Northeast Fisheries Observer Program Database or NEFOP Database) and the landings data (obtained from the CFDBS) using the combined ratio method described in Wigley et al. (2008b). The 2007 discard estimate from the 2008 GARM Report (NEFSC 2008) was updated. The discard ratio estimator consisted of discards of GB winter flounder divided by the sum of all species kept by a particular fleet and was derived with data from the NEFOP Database. Trip discards ratios were then raised to the level of total landings of all kept species from each trip to compute a total discard estimate for each trip. Discards were estimated by quarter and cells with fewer than one trip were imputed using annual values.

Due to a lack of fisheries observer data, prior to 1989 for the trawl fleets and prior to 1992 for the scallop fleet, discard estimates were hindcast back to 1964 based on the following equation:

$$\hat{D}_{t,h} = \bar{r}_{c,2003-2004,h} * K_{t,h} \quad (1)$$

where:

$\hat{D}_{t,h}$ is the annual discarded pounds of GB winter flounder for fleet *h* in year *t*

$\bar{r}_{c,2003-2004,h}$ is an average combined D/K ratio (discarded pounds of GB winter flounder / total pounds of all species kept) for the fleet *h* during either 2003-2004 (for the trawl fleets) or 1992-1998 (for the scallop dredge fleet)

$K_{t,h}$ is the total pounds of all species kept (landed) for fleet *h* in year *t*

U.S. discards of Georges Bank winter flounder were much higher during 1964-1991 (average = 195 mt) than during 1992-2010 (average = 65 mt). During 1964-1975, U.S. discards were predominately (49-87%) attributable to the large mesh groundfish trawl fleet (listed in Table B6 as the small mesh fleet because the minimum codend mesh size prior to 1982 was less than 5.5 in.), but were primarily attributable to the scallop dredge fleet thereafter. Total U.S. discards, primarily from the scallop dredge fleet, were highest during 1976-1991 (ranging between 142 mt and 348 mt), but then declined to a very low level in 1992 (Table B5, Figure B8). This trend is not attributable to the hindcast discard estimation method used for this time period, but rather the trend in fishing effort (days fished) for the U.S. scallop dredge fleet (NEFSC 2010, Figure B9). After 1991, discards were lower and the trend continued to track the trend in scallop fleet fishing effort. During 1992-2003 discards were low, between 9 and 85 mt, but discards increased thereafter, reaching 188 mt in 2007. The spike in discards during 2010 was primarily attributable to the small mesh fleet for which several high discard ratios were observed on several silver hake trips that occurred on Cultivator Shoals. However, the precision of the 2010 U.S.

discard estimate was low (CV = 0.44). Precision of the annual discard estimates varied by fleet and was generally highest for the large-mesh bottom trawl fleet and lowest for the small mesh bottom trawl fleet, with intermediate values for the scallop dredge fleet (Table B5). During most years since 2005, when trip sampling rates increased substantially in the scallop dredge and large-mesh bottom trawl fleets, precision of the annual discard estimates greatly improved, ranging between 0.09 and 0.44 (Table B5).

Discards in Canadian fisheries

Initial estimates of Georges Bank winter flounder discards in the Canadian scallop dredge fleet were included in the stock assessment. The Canadian sea scallop fishery operating on Georges Bank closes when the annual TAC is caught. There are two sea scallop management areas on Georges (based on depth and productivity) with different TAC's. Landing of groundfish bycatch in the sea scallop fishery has been prohibited since 1996, so presumably all winter flounder bycatch in this fishery is discarded. However, observer coverage was very low and consisted of one trip per month during 2001-July of 2007 and two trips per month thereafter. Observer discards of winter flounder in Canadian sea scallop trips was only available for September 2004-December 2010 and was estimated by staff from the CA Division of Fisheries and Oceans (DFO) using the method of Garvaris et al. (2007). The 2004-2010 average of the proportions of Georges Bank winter flounder discards to sea scallop landings in the Canadian scallop fleet (0.029) was multiplied by the sea scallop landings in the Canadian scallop fleet (CSAS 2010; J. Sameoto 2011 pers. comm.) in order to obtain hindcast winter flounder discard estimates for 1982-2003.

Winter flounder discards in the Canadian sea scallop fishery averaged 123 mt during 2004-2010 and ranged from 44 mt to 252 mt (Table B3). Hindcast discard estimates for the fleet during 1982-2003 ranged between 58 and 199 mt. The associated precision of the estimates is unknown.

Estimates of winter flounder discards in the Canadian bottom trawl fisheries were not available from the CA DFO. Since most of the Canadian landings of Georges Bank winter flounder occur as bycatch in bottom trawl fisheries targeting haddock and cod in (H. Stone pers. comm.), presumably some winter flounder discards also occur in these, and possibly other, groundfish bottom trawl fisheries that operate on Georges Bank. Since the mid-1980's, discarding of groundfish in the Canadian groundfish fisheries on Georges Bank (NAFO Division 5Zj) has been prohibited. However, although there is no discarding of groundfish during observed trips, observer coverage of the groundfish bottom trawl fleet is very low and there is no doubt that discarding of winter flounder occurs because discards for species that are more highly sought after in the Georges Bank Canadian groundfish fisheries (e.g., cod, haddock and yellowtail flounder) have been estimated (Gavaris *et al.* 2010).

Another factor that may also have affected winter flounder discarding in Canadian groundfish trawl fisheries are seasonal closures and gear modifications in the haddock fishery to reduce cod bycatch. Since 1994, the Canadian groundfish fishery on Georges Bank has, for the most part, been subject to a seasonal closure during January 1-June 1. Since 2001-2003, mobile gear vessels without at-sea observers have been required to use separator panels to minimize the bycatch of cod when fishing haddock. This gear modification may also have reduce the bycatch of winter flounder in the haddock fishery because the lower panel has an open cod end to allow cod (and possibly flatfish) to escape, while the upper panel captures and retains haddock. The Canadian yellowtail flounder fishery is required to use 155 mm square mesh cod ends, resulting in catches of few yellowtail flounder at sizes < 30 cm (H. Stone pers. comm.). Presumably any winter flounder catches in the yellowtail flounder fishery would be of similar size.

Total discards

During the assessment period, 1982-2010, discards of winter flounder on Georges Bank were higher in the U.S. fisheries prior to 1991 and were higher in the Canadian scallop dredge fishery thereafter (Figure B10). Total discards were much higher during 1982-1991, than thereafter, but total discards slowly increased between 1995 and 2010. Total discards averaged 15% of the total landings during 1982-2010.

Catches

Catches increased during 1964-1972, reaching a peak of 4,608 mt in 1972, but then declined to 2,034 mt in 1976 (Figure B11, Table B3). Catches subsequently increased to 4,290 mt in 1981 then gradually declined to a time series low of 842 mt in 1995. Catches increased to 3,328 mt in 2003 then declined to 1,039 mt in 2007, followed by a slight increase to 2,013 mt in 2009. Total catch in 2010 was 1,544 mt.

Historical catches are likely to have been higher than those observed since 1964 because the U.S. landings alone reached a peak of 4,089 mt in 1945, close to the magnitude of the peak catch during 1964-2010 (4,608 mt), and without the addition of discards, at a time when codend mesh sizes were smaller, and landings from international fleets (Figure B11).

Landings-at-age

Length and age composition data are not collected from the landings or discards of Canadian fleets that fish on Georges Bank, but length and age samples from the U.S. landings were collected by market category and quarter during 1982-2010. Samples are collected for eight market categories (Lemon Sole = 1201, Extra Large = 1204, Large = 1202, Large /Mixed = 1205, Medium = 1206, Small = 1203, Peewee = 1207, and Unclassified = 1200). However, the data were binned as Lemon Sole (1201 and 1204), Large (1202 and 1205) and Small (1203, 1206 and 1207) because the three market categories comprised a majority of the landings during 1982-2010. The annual sampling intensity of lengths ranged between 15 mt and 271 mt landed per 100 lengths measured during 1982-2010 (Table B7). Sampling intensity was lowest during 1996-2000. During 1998 and 1999 there were no Lemon Sole samples (the largest market category size) and only one large sample collected during each of these two years (Table B8) although this market category represented 42% and 45% of the total landings, respectively, during this period (Table B9). After 2000, sampling intensity improved substantially and has been highest since 2004 (Table B7, Figure B12). During 1982-2002, landings were dominated by the Large and Small market categories, but during 2002-2008, the landings were dominated by larger fish (Lemon Sole and Large, Table B9), which was reflected in the increased sampling intensity of these larger fish (Figure B9). Landings of Small fish increased after 2006, as the 2006 year class moved through the fishery, and constituted the predominant market category during 2009-2010 (Figure B13).

During most years, biological sampling of the landings was adequate to construct the landings-at-age (LAA) matrix by applying commercial age-length keys to commercial numbers at length on either a quarterly or half-year basis by market category group (Table B10). The LAA matrix was based on that provided in Brown *et al*. (2000), for 1982-1993, and as provided in the 2008 GARM Report (NEFSC 2008) for 1994-2006. LAA data were updated for 2007-2010 using the allocation scheme presented in Table B11. The LAA matrix (nos. in thous.) includes U.S. and Canadian landings during 1982-2010 for fish of ages 1-7+ (Table B11). The U.S. unclassified market category samples and the Canadian landings were assumed to have the same age compositions as the sampled U.S. landings and the U.S. LAA was adjusted by a raising factor to incorporate the Canadian landings.

Large year classes were trackable in the landings-at-age matrix. For example, large numbers of fish from the 1994 cohort were landed as age 1 fish in 1995, as age 2 in 1996 and as age 3 fish in 1997. Landings of age 1 fish were insignificant during most years (Table B11). During 1982-1984, the landings were dominated by age 3-5 fish and were dominated by age 2-4 fish during 1985-2000. Since 2001, the landings have returned to a predominance of age 3-5 fish. In part, this change was due to a codend mesh size increase (to 6.5 in. square or diamond mesh) occurred in the Georges Bank bottom trawl fishery for groundfish in August of 2002.

Discards-at-age

The annual numbers of lengths sampled by fishery observers, from winter flounder discards in the U.S. bottom trawl and scallop dredge fisheries, were inadequate to characterize discard length compositions during 1989-2000 and 1989-2003 (with the exception of 1997), respectively (Table B12). In addition, length and age composition data for winter flounder discards in the Canadian fisheries are not collected. As a result, U.S. bottom trawl discards-at-age were characterized based on the assumption that fish smaller than the U.S. minimum regulatory size limits were discarded. The minimum size limit for winter flounder in the U.S. bottom trawl fishery was 28 cm during 1986-April, 1994 and has been 30 cm since then. Examination of survey length-at-age data indicates that fish of this size are one year old in the NEFSC fall surveys and two years old in the spring surveys. Therefore, discards-at-age for the U. S. bottom trawl fleet, during 1982-2001, was estimated by dividing the estimated weight of discarded winter flounder from the bottom trawl fleet, during January-June, by the annual mean weights of age 2 fish from the NEFSC spring surveys. Likewise, winter flounder discard weights for July-December were divided by the annual mean weights of age 1 fish from the NEFSC fall surveys. Discards-at-age for the U.S. bottom trawl fleet, during 2002-2010, were estimated by using the discard numbers at length from the NEFOP Database, binned as January-June and July-December, to characterize the proportion discarded at length and ages were determined by applying the NEFSC spring and fall survey age-length keys and length-weight relationships, respectively. Length compositions of discarded fish in the U.S. bottom trawl fishery indicate that for most years during 2002-2010, discarding of all sizes of winter flounder occurred (Figure B14), particularly when Georges Bank winter flounder trip limits were in place during May, 2006 - July 6 of 2009 (5,000 lbs per trip). As of October of 2010, all NE multispecies permit holders that fish on a sector trip were prohibited from discarding legal-sized fish (must land all winter flounder > 30 cm TL).

Length samples of winter flounder discarded in the U.S. scallop dredge fishery were inadequate to characterize discard length compositions during 1989-2003, with the exception of 1997 (Table B12). The post-2003 discard length composition data suggested that, in general, all sizes of winter flounder were discarded in the U.S. scallop dredge fishery, but that catches of winter flounder smaller 30 cm are very low (Figure B15). Similar scallop dredges are used by the Canadian scallop fleet (H. Stone, pers. comm.). The Canadian scallop dredge fleet has been prohibited from landing groundfish since 1996 and winter flounder is a low-value species in CA in relation to cod, haddock and yellowtail flounder (there is no existing directed fishery for winter flounder). Given these considerations, discards-at-age for the both the U.S. and Canadian scallop dredge fisheries were estimated by scaling up the LAA by the ratio of total scallop dredge discards to total landings. During years when sufficient numbers of length samples of winter flounder discards were available, 1997 and 2004-2010 (the 2009 and 2010 discard length samples were combined to derive the 2010 discard length composition), the annual discard length frequency distributions were used to characterize the proportion of discards-at-length for both the U.S. and Canadian scallop dredge fleets and the NEFSC fall survey age-length keys and length-weight relationships were applied to the combined annual discard weights (U.S. and CA) because most of the U.S. discards occurred during the second half of the year.

Discards-at-age (numbers in thous.) were computed for ages 1-7+. Discards occurred across all age categories because they are primarily driven by discarding in the U.S. and Canadian scallop dredge fleets. Numbers of discarded fish shifted from primarily age 2-4 fish during 1982-1997 to age 3-5 fish during 1998-2003 (Table B13). The total numbers of fish discarded were consistently much lower during 2004-2010, when the fishing in Closed Areas I and II was mostly prohibited for groundfish trawlers and limited for scallop fishing. However, the range of ages that were discarded broadened to include mostly ages 2-5. Discards of age 1 fish, which occur primarily in bottom trawl rather than scallop dredge fisheries, were highest during 1982-1985; a time when there was no minimum landings size limit in effect and the minimum codend mesh size was smallest (5.5 inches) for groundfish trawlers. During 1982-2010, the numbers of age 1 discards decreased, presumably because the minimum codend mesh size required in groundfish bottom trawls was increased to 6.5 inches.

Catch-at-age

Components of the catch-at-age (CAA) consisted of the combined U.S. and Canadian landings-at-age and discards-at-age for the U.S. large-mesh and small-mesh bottom trawl fleets plus the U.S. and Canadian scallop dredge fleets, during 1982-2010, for ages 1-7+ (Table B14). During 1982-1984, the CAA contained a broad range of ages, but was dominated by ages 2-5 and had the highest numbers of fish aged 6 and older (Table B15, Figure B16). The CAA changed from this more stable age composition to one dominated by ages 2-4, during 1985-1996. During 2000-2005, the catch composition changed back to a predominance of age 3-5 fish and contained more older fish (ages 6 and older), but at the higher levels observed during 1980-1984. The catches were dominated by age 2-4 fish during 2008-2010 as the 2006 year class was harvested by the fishery (Table B15, Figure B16).

Mean weights-at-age in the catch remained relatively stable during 1985-1996 across most ages, but then declined to a lower level during 1997-2001, for ages 3-5 possibly due, in part, to poor sampling of large fish during part of this time period (Figure B17, Table B16). Mean weights-at-age reached their highest levels during 2003-2007, but then declined through 2010 to some of their lowest levels since 1982.

Term of Reference 2: ***Present survey data being considered and/or used in the assessment (e.g., regional indices of abundance, recruitment, state and other surveys, age-length data, etc.). Characterize uncertainty in these sources of data.***

Research Survey Data

Stratified, random bottom trawl surveys conducted by the NEFSC during the spring and fall provide long time series of fishery-independent indices for Georges Bank winter flounder. The fall and spring surveys have been conducted since 1963 and 1968, respectively, and sampling on Georges Bank has generally occurred during October and April, respectively. The strata set used to calculate abundance and biomass indices from the two NEFSC surveys included offshore strata 13-23 (Figure B18). Stratum 23 was included in the strata set for the 2008 stock assessment because age analyses indicated that most fish within the stratum exhibited the faster, Georges Bank growth type rather than the slower growth type of the other two stocks (NEFSC 2008). Winter flounder catches during NEFSC surveys are also highest in the eastern, Georges Bank portion of stratum 23 (NEFSC 2008). A portion of stratum 23 lies within SA 521, for which commercial catches are assigned to the SNE/MA winter flounder stock. Based on a GIS analysis, 46% of stratum 23 is located within Georges Bank SA 522 and the remainder is located in SA 521. However, more than half (53%) of stratum 23 lies within Closed Area 1 and cannot be routinely fished by trawlers targeting winter flounder. Of the open area portion of stratum 23 which can be fished, 74% lies within SA 521, but this is only a small portion of the total area of SA 521.

The SDWG discussed whether the overlap of stratum 23 with SNE-MA SA 521 was a concern with respect to its effect on biological sampling of commercial catches or assessment model tuning indices. However, because of the differences in growth rates between the two stocks, biological samples from catches in SA 521 are readily assigned to the correct stock, eliminating such concerns. Winter flounder catches during both the spring and fall surveys are very low in the open portion of stratum 23 that lies within SA 521, suggesting that commercial catches of winter flounder from this portion of SA 521 are also likely low, and therefore, are not expected to influence the assessment results. As a long-term solution to this issue, splitting stratum 23 into two strata, is planned for the 2011 fall survey.

Relative abundance and biomass indices of Georges Bank winter flounder derived from Canadian stratified random bottom trawl surveys, conducted in strata 5Z1-4 (Figure B19) during February by the Maritimes Region staff from the Division of Fisheries and Oceans, were also included in the assessment. The survey design and sampling protocols are provided in (Chadwick et al. 2007).

Beginning in 2009, the NEFSC SRV *Albatross IV* was replaced with the SRV *Henry B. Bigelow*. The new vessel is quieter and the reduced spacing between the rockhoppers on the footrope has improved the catchability of winter flounder. In order to extend the NEFSC spring and fall survey time series beyond 2008, stock-specific, length-based vessel calibration factors were applied to the Bigelow catches of Georges Bank winter flounder to convert them to Albatross equivalents. The data and methods used to estimate the calibration factors are described in Appendix B3. The aggregate catch number calibration factor for winter flounder, for combined seasons, is 2.490 and the aggregate catch weight factor, for combined seasons, is 2.086 (Miller et al. 2010). A fourth order polynomial model fit to data for the Georges Bank stock region, incorporating a mean ratio of the vessel swept areas of 0.5868 (Bigelow to Albatross), was used to calculate the calibration factors-at-length (Figure B20) that were used to convert the 2009-2010 Bigelow survey indices to Albatross units for use in the VPA model (Table B17).

Relative biomass (stratified mean kg per tow) and abundance (stratified mean number per tow) indices are presented for the NEFSC spring (April, 1968-2010) and fall (October, 1963-2010) bottom trawl surveys , as well the Canadian spring bottom trawl surveys (February, 1987-2010, (Table B18). NEFSC survey indices prior to 1985 were standardized for gear changes (weight = 1.86 and numbers = 2.02, Sissenwine and Bowman 1978) and trawl door changes (weight = 1.39 and numbers = 1.4, Byrne and Forrester 1991).

Despite considerable inter-annual variability, the NEFSC fall survey relative abundance indices showed an increasing trend during the 1970's, followed by a declining trend during the 1980s to a time series low in 1991 (Figure B21). Thereafter, relative abundance increased through 2001 then declined to a level below the 1963-2009 median during 2005-2007. In 2009, fall relative abundance reached the second highest point in the time series, but declined drastically in 2010 to a level slightly below the time series median. Trends in the NEFSC spring survey relative abundance indices exhibited more inter-annual variability, but were similar to the fall survey time series after 1982. NEFSC spring survey abundance indices were at record low levels during 2004-2007. The second highest abundance index of the time series occurred in 2008. However, most of the fish were caught at two consecutively sampled stations and relative abundance was much lower in 2009 and was at the time series median level in 2010. Relative abundance trends in the Canadian survey were similar to those in the NEFSC spring survey during most years but were of greater magnitude during blocks of years (1988-1990 and 1993-1997). Similar to relative abundance indices from the NEFSC spring surveys, indices from the Canadian surveys were at the lowest levels observed during 2005-2007 but were well below the time series median in 2009 and 2010.

In order to estimate catchability coefficients for each survey (q) in the VPA, minimum population size estimates were computed based on swept areas of 0.011 nmi^2, for NEFSC surveys conducted by the Albatross and Delaware, and 0.012 nmi^2 for the CA surveys. During NEFSC and CA surveys, tows are conducted for 30 minutes, between winch lock and re-engage, at a target speed of 3.5 knots (Azarovitz 1981; Chadwick et al 2007). Minimum population sizes-at-age (000's) included in the VPA included: the U.S. fall (1981-2010, ages 0-6 lagged forward one year and age, Table B19) and spring bottom trawl surveys (1982-2010, Table B20) and the Canadian spring bottom trawl surveys (1987-2010,Table B21). Age samples of winter flounder are not collected during Canadian bottom trawl surveys so the NEFSC spring survey age-length keys, augmented during some years with commercial age-length keys from the first quarter of the corresponding year (when larger fisher were caught), were used to partition stratified mean numbers-at-length from the Canadian surveys into numbers-at-age. Although the numbers-at-age were highly variable, large cohorts appeared to track through the numbers-at-age matrices, for the NEFSC surveys, for the 1980, 1987, 1994, 1998-2001, and 2006 cohorts (Figure B22). Age truncation occurred between 1983 and 1997, during which time the population was dominated by four age groups rather than seven or more. During 1997-2004, the age structure improved but has since become truncated again. Both the U.S. and Canadian spring surveys showed reduced numbers of age 1-3 fish (and age 4 fish in the CA surveys) during 2000-2007. The Canadian spring survey did not show the same magnitudinal increase in age 1-6 fish that was evident in the NEFSC spring surveys during 2008-2010.

Term of Reference 3: ***Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series (integrating results from TOR-5), and estimate their uncertainty. Include area-swept biomass estimates. Investigate if implied survey gear or catchability estimates are reasonable. Include a historical retrospective analysis to allow a comparison with previous assessment results.***

Model input data

A series of VPA model runs was conducted for the current assessment using the NOAA Fisheries Toolbox (NFT) ADAPT VPA (Gavaris 1988) version 3.0.3. (NFT 2010) and data for 1982-2010. Retrospective analyses, for terminal years 2001-2009, were conducted for each model run. Input data and descriptions of the different model formulations are presented in Table B22. An initial population analysis was conducted to provide a "bridge" from the 2008 GARM assessment results (NEFSC 2008) by updating the 2008 model configuration. However, the model results indicated that stock estimates for age 2 fish were no longer estimable in the terminal year +1 (CV = 1). As a result, all subsequent model runs included stock estimates for ages 3-6 in 2011. Run 4 included the new three-year moving window maturity schedule (described above in the Growth and Maturity section) and the addition of Canadian scallop dredge discards with an M assumed of 0.2. The Run 5 model formulation was the same as for Run4, but included the Working Group's recommended increase in M to 0.3 (see M section above).

Sensitivity Run 1 evaluated the effect of the new maturity schedule on the SSB estimates. Sensitivity Runs 2 and 3 evaluated the effects of omitting Canadian spring survey as a tuning index and down-weighting of the Canadian survey residuals, respectively. The Canadian survey was responsible for the highest percentage (43%) of the total variance of all three tuning indices. In particular, Canadian survey indices for ages 1-3 comprised the highest percentages of the total variance of indices from all three surveys (7.1%, 8.3% and 9.8%, respectively). However, the Working Group recommended against selecting subsets of ages from the tuning indices. For Sensitivity Run 3, the Canadian survey residuals were down-weighted by 0.42, which was computed as the squared average of the ratios of the mean CVs of each of the U.S. survey indices to the average CV of the Canadian survey indices.

Results

There was little difference in the VPA estimates of average F, SSB and age 1 recruitment for the updated 2008 GARM run versus Run 4 (Figure B23). The latter run included the the new maturity schedule and the addition of discards from the CA scallop dredge fleet. The largest difference in F, SSB and R estimates between these two runs and Run 5 was attributable to the increase in M from 0.2 to 0.3 . For Run 5, estimates of F were lower and SSB and R estimates were higher than for the other two runs (Figure B23). The result of applying the new maturity schedule was a 4.5-28.4% reduction, 14% on average, in the annual SSB estimates during 1982-2010 (Figure B24).

Model diagnostics

Trends in the residuals patterns were evident for a number of ages within each of the three sets of VPA calibration indices, with variability by age and year. For example, residuals trends from NEFSC spring surveys were the worst for age 2 and age 3 fish. Residuals were positive for age 2 fish during 1990-1996, and for age 3 fish during 1983-1987, but were negative for age 3 fish during 2001-2007 (Figure B25). The Canadian spring survey indices for ages 2-4 showed major residuals trends (Figure B26), both positive and negative, but the patterns differed from those evident in the NEFSC spring surveys. For example, age 3 and age 4 fish showed similar residuals trends; positive during 1988-1991 and 1993-1997, but negative during 1998-2010. Residuals trends for the NEFSC fall survey abundance indices were the worst for older fish,ages 5-7 (actually ages 4-6 lagged forward one year and age) and were generally positive from 2002 or 2003 onward (Figure B27).

VPA estimates of survey catchability coefficients (*q*), by age, indicated that catchabilities for all three surveys generally increased with age (Figure B28). Catchabilities were higher for the NEFSC fall surveys than the NEFSC spring surveys (e.g., $q = 0.20$ and 0.28 for age 6, respectively), but *q*s-at-age between the two surveys were not significantly different. Catchabilities for the Canadian spring surveys can be compared across ages but not between surveys because the vessels and gear were different. The catchabilities of ages 1-3 fish were significantly lower than for ages 5-7+ fish (Figure B28).

Retrospective analyses

Similar to the 2008 GARM assessment results, very mild retrospective patterns were present for terminal year estimates of fishing mortality (overestimation during 2006-2009 and underestimation during 2002-2005) and spawning stock biomass (underestimation during 2006-2009 and overestimation during 2002-

2005, Figure B29). There was no retrospective pattern for terminal year age 1 recruitment, but the estimates were highly variable (Figure B29).

Rrelative differences in the estimates of average F, SSB and age 1 recruitment, during year *t* (for 2001-2009) versus 2010, are presented in Figure B30. Run 5 was selected as the final model run because the range of retrospective errors in F and SSB was narrower than for Sensitivity Runs 2 and 3 (Table B23). For Run 5, the retrospective error in fishing mortality ranged from -48% in 2002 to +42% in 2009 and retrospective error in SSB ranged from -13% in 2008 to +43% in 2002 (FigureB30).

Estimates of fishing mortality, spawning stock biomass and recruitment

Estimates of January 1 population size (numbers, 000's), average fishing mortality rates (F on ages 4-6), and spawning stock biomass (mt), from the final VPA model run, are presented in Tables B24-B26, respectively. Fishing mortality rates were highest during 1984-1993, ranging between 0.57 and 1.17, then declined to levels ranging between 0.31 and 0.51 during 1994-1998 (Figure B31, Table B27). Fishing mortality rates were low (0.26-0.27) during 1999 and 2000, then increased rapidly to 0.85 in 2003 and was followed by a rapid decline to the second lowest level in the time series (0.20) in 2006. Fishing mortality increased slightly during 2007-2009, but then declined to 0.15 in 2010.

SSB declined rapidly from a time series peak of 17,380 mt in 1982 to 6,256 mt in 1985, then increased slightly through 1987 to 8,082 mt (Figure B31, Table B27). After 1987, SSB declined again to a time series low of 3,424 mt in 1995. SSB subsequently increased to 13,790 mt in 2000, but then declined to 5,305 mt in 2005. Thereafter, SSB increased and totaled 9,703 mt in 2010.

Trends in age 1 recruitment showed several periods of rise-and-fall. Recruitment increased from 8.3 million fish in 1983 to a time series peak of 26.3 million fish in 1988, and then declined to 5.2 million fish in 1993 (Figure B31, Table B27). Recruitment increased again to fairly high levels during 1995-1999 (16.2-22.8 million fish) then declined to the second lowest level on record (5.5 million fish) in 2004. Recruitment increased to 18.8 million fish in 2008, but then declined to the lowest level in 2009 (4.0 million fish). Recruitment increased to a very high level (22.5 million fish) in 2010; an estimate that was based on the partial recruitment value for age 1 fish multiplied by the fully-recruited F. The 2011 recruitment value is uncertain because it represents the geometric mean of the 2003-2009 recruitment values. Bootstrapped estimates of the 2011 stock sizes-at-age and the 2010 fishing mortality rates-at-age are presented in Tables B28 and B29, respectively.

A comparison of the estimates of F, SSB and R, from the final model (Run 5) versus the two sensitivity runs indicated, that in recent years, slightly higher F and lower SSB and R values were estimated when the CA spring survey was included as a tuning index (in the final model, Run 5) rather than when the CA survey was omitted or downweighted (Figure B32). As discussed previously in the Retrospective Analyses section, the two sensitivity runs resulted in increases in retrospective error in F and SSB in comparison to Run 5.

TOR 4: ***Perform a sensitivity analysis which examines the impact of allocation of catch to stock areas on model performance (in TOR-3).***

The SDWG interpretation of TOR4 was that the variance of the commercial landings due to the 1995 and later area-allocation scheme should be used as the basis for estimating the magnitude of landings that might be lost or gained for the stock-specific assessments, and that the assessment models should be run with those potential biases incorporated and the results presented. For the Georges Bank stock, annual catches consisted of the U.S. landings and discards and the Canadian landings and discards. Precision estimates for the Canadian landings and discard estimates were not provided by the CA DFO, so they were assumed to be the same as the precision estimates for the US landings and discards.

For the Georges Bank winter flounder stock, total landings for 1995-2010 have a calculated Proportional Standard Error (PSE; due to the aforementioned commercial landings area-allocation procedure) ranging from 0.7% to 1.3% (Table B30). The 1995-2010 mean PSE of 0.9% was substituted for the 1982-1994 PSEs of the landings. The total discard PSEs during 1995-2010 ranged from 1% to 56%. The 1995-2010 mean PSE of 26% was substituted for the PSEs of the 1982-1994 discards. Because the PSEs for the landings are low, and the landings accounted for 69-94% of the total catch during 1982-2010, the total catch-weighted annual PSEs ranged from 1.2% to 8.2% and averaged 3.9% (unweighted) for the 1982-2010 time series.

The SDWG developed an exercise using the 2008 GARM-III assessment data and ADAPT VPA model in an initial response to TOR4 and concluded that the application of a annually varying unidirectional "bias-correction" in such an exercise provides stock size estimates and BRPs that scale up or down by about the same average magnitude as the gain or loss (SDWG52 WP3).

Since development of SDWG WP3, the SDWG concluded that the calculated variance of the area-allocated commercial landings likely underestimates the true error. More work was done to estimate the error in the commercial landings due to misreporting of commercial landings to statistical area at allocation level “A” reporting level in mandatory Vessel Trip Reports (Palmer and Wigley MS 2011). Vessel monitoring system (VMS) positional data from northeast United States fisheries for 2004-2008 were used to validate the statistical area fished and stock allocation of commercial landings derived from the VTRs. The accuracy of the VMS method relative to the VTRs was assessed using haul locations and catch data recorded by at-sea observers. This work was performed for several New England groundfish species. The perceived under-reporting of statistical areas in the VTR data led to minor (< 5%) differences in the overall species landings allocations. Only nine stocks in the five year time-series exhibited differences in stock allocations exceeding 2.0% (2004: northern and southern silver hake, ± 3.0%; 2006: northern and southern windowpane flounder, ± 4.7%; 2007: Georges Bank winter flounder, 2.4%; 2008: Georges Bank winter flounder, 2.4%, Southern New England/Mid-Atlantic winter flounder, -3.2%, and northern and southern windowpane flounder, ± 3.4%). Given the magnitude of these errors, the SDWG elected to update the exercise by adding an additional 5% PSE to the PSE values shown in Table B30 for the Georges Bank total landings during 1995-2010. This increased the 1995-2010 average landings PSE from 0.9% to 5.7%, and increased the average 1982-2010 catch PSE from 4.0% to 6.2%, with a range of 2.7% in 1983 to 13.7% in 2010.

The catch in the final assessment model was increased/decreased by the annually varying catch PSEs and models were re-run to provide an additional measure of the uncertainty in assessment estimates. As noted in SDWG WP3, the application of a annually varying "bias-correction" in one direction in such an exercise provides stock size estimates that scale up or down by about the same average magnitude as the gain or loss. For the final VPA model results, fishing mortality did not change, on average (out to three decimal places), and the range in 2010 F was 0.154 to 0.162. SSB changed by – 1.0% and +7.9%, on average, and the range in 2010 SSB was 9,636 mt - 10,504 mt (Figure B33).

Term of Reference 5: ***Examine the effects of incorporating environmental factors in models of population dynamics (e.g., spring water temperatures in an environmentally-explicit stock recruitment function).***

Winter flounder spawn in winter and early spring in estuaries along the mid-Atlantic, southern New England and Gulf of Maine (Able and Fahay 2010) as well as in continental shelf waters on Georges Bank during March-May (Smith 1985). There is also recent evidence of more coastal spawning in both Southern New England (Wuenschel et al. 2009) and the Gulf of Maine (Fairchild et al. 2010). In southern New England, Manderson (2008) found that overall recruitment was linked to spring temperatures, presumably by acting on larvae, settlement stage, and/or early juveniles. Further, Manderson (2008) found that young-of-the-year abundance among 19 coastal nurseries became more synchronized in the early 1990's and argued that increased frequency of warm springs was creating coherence in early life stage dynamics among local populations.

The specific mechanism linking temperature to recruitment was not defined by Manderson (2008), but temperature is an important parameter in many ecological processes affecting winter flounder. In a mesocosm study, Keller and Klein-MacPhee (2000) found that winter flounder egg survival, percent hatch, time to hatch, and initial size were significantly greater in cool mesocosms. Further, mortality rates were lower in cool mesocosms and related to the abundance of active predators. In the laboratory, Taylor and Collie (2003) found that consumption rates of sand shrimp were lower at lower temperatures implying lower predation pressure at colder temperatures. In the field, Stoner et al. (2001) found that settlement stage winter flounder prefer colder waters and that the importance of temperature in defining juvenile habitat decreases through ontogeny. Thus, temperature has multiple effects on the early life history of winter flounder and colder temperatures in general lead to higher survival and recruitment.

The relationship between winter flounder recruitment and temperature identified by Manderson (2008) did not include the effect of population size. The relationship between stock size and subsequent recruitment is generally poor in marine fishes (Rothschild 1986) but can have explanatory power. To examine the combined effect of environment and spawning stock biomass on recruitment, the goal was to develop environmentally-explicit stock-recruitment relationships that include temperature and related environmental variables for the three stocks of winter flounder. As a basic framework, the approach of Hare et al. (2010) was followed. The resulting models could be used in short-term forecasts based on fishing and temperature scenarios (fixed patterns of temperature variability over several years) and long-term forecasts based on fishing and temperature projections from general circulation models. The methods and results of the analysis are described in Appendix B2.

The conclusion from the analysis was that recruitment in the coastal stocks of winter flounder (GOM and SNE-MA) were linked to air temperatures during winter, when spawning occurs, but there was no evidence for an air temperature effect on recruitment in the Georges Bank stock; the environmentally-explicit models (which also included a Gulf Stream index) did not provide a better fit compared to the standard stock recruitment model. The Georges Bank stock experiences water temperatures that are affected by both local air temperatures and more importantly, large-scale advective supplies of relative cold, fresh water associated with the Labrador Current. Examining other environmental variables which may affect recruitment in the Georges Bank stock (e.g., hydrographic circulation patterns on Georges Bank in relation to larval abundance) is listed below as a future research recommendation.

Term of Reference 6: ***State the existing stock status definitions for "overfished" and "overfishing".***

Then update or redefine biological reference points (BRPs; point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, and F_{MSY}) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

Existing biological reference points (BRPs)

The specification of FMSY and BMSY reference points relies on a stock-recruitment relationship. As a result, the 2008 GARM Biological Reference Point Review Panel (NEFSC 2008) concluded that MSY-based BRPs should be adopted when the stock-recruitment relationship is informative, and if not, then the Panel recommended the use of F40%MSP as a proxy for FMSY, similar to the previous recommendation from a separate BRP Working Group for many of the groundfish stocks (NEFSC 2002a), and a BMSY proxy computed using the non-parametric, empirical approach.

For Georges Bank winter flounder, the 2008 GARM BRP Review Panel (O'Boyle et al. 2008) concluded that the Beverton-Holt stock-recruit relationship, derived using data from the VPA model, was uninformative regardless of whether the model was fit without a prior (*h*=1) or with a prior (the fit was highly dependent on the assumed prior on unfished recruitment, R_0). Thus, the Panel recommended that a non-parametric empirical approach be used to estimate biological reference points based on: 1) the final VPA model results, 2) the estimate of F40%MSP as a proxy for F_{MSY} (derived from a per-recruit model using the most recent five-year average of fishery selectivity and weights-at-age and the maturity-at-age time series average), and 3) a long-term (100-year) stochastic projection using the cumulative distribution function of observed recruitment (1983-2007 recruitment at age 1, the 1982-2006 year classes) to estimate MSY and SSBMSY40%. The existing BRPs, F40% and SSB40%, were adopted at the 2008 GARM (NEFSC 2008) and were promulgated in 2009 in Amendment 16 to the Northeast Multispecies Fishery Management Plan (NEFMC 2009). The existing biomass target is SSBMSY at 40% MSP (= 16,000 mt) and the minimum biomass threshold is 50% of the target (= 8,000 mt). The fishing mortality threshold is F40%MSP (= 0.26). Amendment 16 defines the fishing mortality target as the mortality associated with the Annual Catch Limit (ACL).

Candidate biological reference points

For Georges Bank winter flounder, two sets of candidate BRPs (i.e., FMSY and SSBMSY versus F40% and SSB40%) were brought forward from the current assessment for review by the SARC because the SDWG could not reach consensus on whether the stock-recruit relationship from the Beverton-Holt model was informative, and consequently, whether FMSY was well-estimated. Both sets of BRPs were estimated similar to the methods used for the 2008 GARM (NEFSC 2008), as summarized in the preceeding paragraph.

FMSY was estimated from a Beverton-Holt model which incorporated R (age 1) and SSB estimates from the final VPA model (1982-2009 year classes) with an assumed prior on steepness (*h* = 0.8 and SE = 0.09, based on the values reported for Pleuronectids in Myers *et al*. (1999)). . In addition, a per-recruit model (Thompson and Bell 1934) was used to estimate an F_{MSY} proxy of $F_{40\%\ MSP}$. Input data to both models included the most recent five-year averages (2006-2010) of fishery selectivity-at-age, proportion mature-at age, and weights-at-age from the final VPA model (Table B31).

Parameter estimates from the Beverton-Holt model are shown in Table B32. Similar to the 2008 GARM results, the steepness parameter for the Beverton-Holt model could not be estimated (h=1) without assuming a prior. This constant recruitment even at low spawning stock sizes is not theoretically feasible. When the steepness prior was set to 0.8, with a standard error of 0.09, the h estimate was 0.85 (CV = 0.08; 80% CI = 0.74, 0.94) and the FMSY estimate was 0.50 (CV=0.22; 80% CI = 0.39, 0.69). Precision estimates were obtained from an MCMC analysis with 1,000 realizations (100,000 MCMC iterations with a thinning rate of 100). The steepness log-likelihood profile indicated that the steepness prior was highly influential in determining the FMSY estimate (Table B33). Both sets of candidate BRPS presented to the SARC are shown in Table B34, along with the existing BRPs.

The SARC expressed concerns about how well the Myers *et al*. (1999) steepness value for Pleuronectids was estimated and that the values of M upon which their models were based were lower (≤ 0.2) than the value of 0.3 used in the SARC 52 winter flounder assessments. The SARC noted that the stock-recruitment data for the Georges Bank stock was less informative than the SNE/MA data for predicting recruitment at low spawner levels, making direct estimation of the spawner-recruit relationship difficult without external information. The SARC also concluded that steepness values should be similar between winter flounder stocks. Therefore, the steepness log-likelihood profiles of the two stocks (Table B33 for the Georges Bank stock) were used in selecting fixed values for steepness with which to estimate FMSY for each stock. Fixed values of steepness were chosen that were as similar as possible between the stocks, but which also provided good fits to the stock-recruit data for each stock. Steepness values that are within two units of the minimum AIC were considered to be realistic values for each stock (Burnham and Anderson, 2002). Therefore, the SARC recommended that steepness be set at the largest value such that ΔAIC = 2, for the SNE/MA stock (steepness fixed at 0.61, Figure B34), and at the smallest value such that ΔAIC = 2 for the Georges Bank stock (steepness fixed at 0.78, Figure B34). The final candidate FMSY estimate resulting from fixing steepness at 0.78 is 0.42 (Table B33). Precision estimates for FMSY were not possible due to fixing the steepness parameter. Results from the model fit and standardized residuals are shown in Figure B35. Trends in the residuals alternate between positive and negative for most of the time series. Estimates of SSBMSY and MSY, and their associated precision, were estimated using the method described above for the 2008 GARM; a 100-year stochastic projection that incorporated the parameter estimates from the Beverton-Holt model and the cumulative distribution function of observed recruitment (1983-2010 recruitment at age 1, the 1982-2009 year classes). Candidate BRPs estimated for the Georges Bank winter flounder stock which were used to determine 2010 stock status were: FMSY (Fthreshold) = 0.42; SSBMSY (Btarget) = 11,800 mt; ½ SSBMSY (Bthreshold) = 5,900 mt and MSY = 4,400 mt (Table B35).

Term of Reference 7: ***Evaluate stock status (overfished and overfishing) with respect to the "new" BRPs (from TOR 6), and with respect to the existing BRPs (from a previous accepted peer review) whose values have been updated.***

<u>Stock status</u>

In 2010, overfishing was not occurring because the 2010 fishing mortality rate (= 0.15) was below the value of FMSY (= 0.42, Table B35). The stock was also not overfished in 2010 because spawning stock biomass in 2010 (= 9,703 mt) was above the SSB_{MSY} threshold (= 5,900 mt, Table B35, Figure B36).

The results of a bootstrap analysis (1,000 iterations) suggested that the 2010 estimates of average F (on fully recruited ages 4-6) and spawning stock biomass were fairly precise with CVs of 20% and 24%, respectively. There was an 80% probability that the 2010 F estimate was between 0.12 and 0.21 and that the 2010 SSB estimate was between 7,304 mt and 12,578 mt (Figure B37).

In the current assessment, the assumed value for M was increased from 0.2 to 0.3. As a result, the SDWG concluded that a comparison of the 2010 F and SSB estimates from the current assessment with the existing reference points was not appropriate.

The revised assessment model alters the historical perception of stock status. Four changes from the previous assessment are: 1) a change of M from 0.2 to 0.3 and 2) a new maturity schedule, 3) the addition of Canadian discards, and 4) a change to MSY-based BRPs rather than proxies. Based on the results from the revised assessment model, the stock was overfished during 2004 aqnd 2005. During 2006-2010, spawning stock biomass was above the new biomass threshold of 5,900 mt, but did not reach the new biomass target of 11,800 mt. This contrasts with the 2008 assessment which indicated the stock was overfished in 2007.

Term of Reference 8: ***Develop and apply analytical approaches and data that can be used for conducting single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs) under a set of alternative harvest scenarios. If the stock needs to be rebuilt, take that into account in these projections.***

a. ***Provide numerical short-term projections (3-5 yrs, or through the end of the rebuilding period, as appropriate). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions about the most important uncertainties in the assessment (e.g., terminal year abundance, variability in recruitment). Take into consideration uncertainties in the assessment and the species biology to describe this stock's vulnerability (see "Appendix to the SAW TORs") to becoming or remaining overfished, and how this could affect the choice of ABC.***
b. ***Develop plausible hypotheses (e.g., mixing among the three stocks) which might explain any conflicting trends in the data and undertake scenario analyses to evaluate the consequences of these alternate hypotheses on ABC determination.***

Projections

Stochastic medium-term projections of future stock status, during 2011-2017, were conducted based on results from the final VPA model run and the candidate BRPs using AGEPRO software (v. 3.3) from the NOAA Fisheries Toolbox (NOAA 2009). Maturity-at-age and mean weights and fishery selectivity patterns-at-age, estimated for the most recent 5 years of the assessment (2006-2010), were included in the projections to reflect current conditions in the stock and fishery (Table B31). The projections assumed that a catch of 2,118 mt (for the FMP Framework 44 fishing year beginning May 1) would be landed as the calendar year catch in 2011. The projections incorporated uncertainty in the current population estimate, via bootstrap replicates (N=1,000), and variability in predicted recruitment. A parametric Beverton-Holt model with log-normal error was used and recruitment variability was generated by randomly sampling from the estimated error distribution of the fitted stock–recruitment model.

The regulations require rebuilding of the Georges Bank stock, with at least 75% probability, by 2017. The projections indicated that rebuilding to SSBMSY (= 11,800 mt) is expected to be achieved with 78% probability in 2012 and 93% probability in 2012 when fishing at 75% of FMSY (=0.315) with a catch of 2,118 mt in 2011 (Figure B38). Projected SSB, during 2011-2017, and catches, during 2012-2017, and their 10% and 90% confidence intervals are shown in Figure B39.

Stock Vulnerability

Appendix to the SAW TORs: "*Vulnerability. A stock's vulnerability is a combination of its productivity, which depends upon its life history characteristics, and its susceptibility to the fishery. Productivity refers to the capacity of the stock to produce MSY and to recover if the population is depleted, and susceptibility is the potential for the stock to be impacted by the fishery, which includes direct captures, as well as indirect impacts to the fishery (e.g., loss of habitat quality).*"

Vulnerability, productivity and susceptibility of the Georges Bank winter flounder stock using several methods. Uncertainty was evaluated using model estimates of precision and qualification of other uncertainties. The age-based VPA model and associated MSY reference point evaluations provide a relatively comprehensive and synthetic evaluation of vulnerability that is entirely consistent with stock status determination and projection. With respect to status determination, vulnerability and susceptibility were accounted for with regards to estimation of F in 2010, but precision estimates for F_{MSY} were not possible due to the use of a fixed steepness value in the Beverton-Holt stock-recruit model. Stock vulnerability and susceptibility were also accounted for in the stock rebuilding projection. All components of productivity (reproduction, individual growth, and survival) were also explicitly accounted for in stock status determination and projections. Reproduction was monitored as age-1 recruitment, and projected as a function of SSB (the product of abundance, weight- and maturity-at- age). Individual growth was monitored as empirical size at age, and projected as recent mean size at age. Survival was accounted for based on model estimates of fishing mortality and selectivity as well as assumed natural mortality, which was informed by tagging analysis.

Uncertainties that were not accounted for by the VPA and reference point models were evaluated using model diagnostics. Standard model diagnostics (e.g., residual analyses, retrospective analyses) were used for model validation. Retrospective patterns were not problematic for Georges Bank winter flounder.

Vulnerabilities that were not accounted for from the assessment and reference point models were evaluated using exploratory modeling, habitat observations and testing the influence of environmental factors on recruitment dynamics. The Georges Bank winter flounder stock is harvested primarily by US bottom trawlers engaged in the large-mesh, multispecies groundfish fisheries. Bycatch and discards are monitored and managed through Annual Catch Limits with Accountability Measures for exceeding those limits. However, a small portion of the stock (5-17% of the total catch during 2004-2010) is not regulated by the US, yet is susceptible to fishing (i.e., incidental catches) by the Canadian scallop dredge and groundfish bottom trawl fleets. Winter flounder discards in the latter fleet are unknown.

An additional consideration of vulnerability and productivity are the implications of increased natural mortality from predation. Consumption of winter flounder by other fishes, birds and marine mammal predators, particularly seals, may be increasing if these predator populations are increasing.

Potential for stock mixing

Historical tagging studies (e.g., Howe and Coates 1975) indicate that there is limited mixing of fish among the three current stock units, with about 1%-3% between the GOM and SNE/MA, about 1% between GBK and SNE/MA, and <1% between GOM and GBK. Historical meristics studies based mainly on fin ray counts also indicate a separate GBK stock (Kendall 1912; Perlmutter 1947) or separate GOM, GBK, and SNE stocks (Lux et al. 1970; Pierce and Howe 1977). Growth and maturity studies also support the distinction of at least three stock areas (Lux 1973; Howe and Coates 1975; Witherell and Burnett 1993), with GBK growing and maturing the fastest and GOM fish the slowest.

The SDWG has initiated research pursuing the use of a more complex model (i.e., Stock Synthesis) to maintain separate fishery and survey catch for the three current stock units, while allowing a small amount (a few percent) of exchange between the stock units based on information from historical tagging. However, development of that research has not progressed sufficiently to be made available for peer review at this time.

Term of Reference 9: ***Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.***

Research recommendations from previous assessments

2002 GARM

1. *Investigate whether NEFSC survey stratum 23 includes winter flounder from the Georges Bank stock.*

Most fish in stratum 23 exhibited much faster Georges Bank-type growth rates, so stratum 23 has been included in stock assessments since the 2008 GARM.

2. Request additional observer coverage of GB SD and BT fisheries.

As of 2004, sea day allocations have been based on effort patterns in the scallop dredge and large mesh (codend mesh > 5 in.) bottom trawl fleets and NEFOP funding has increased.

2005 GARM

1. Include discards in future assessments.

US fishery discards were included in the 2008 GARM assessment.

2008 GARM

1. *Explore assessment approaches that consider all three stocks with interaction amongst them.*

An SS3 modeling exercise to explore this approach is currently in progress at the NEFSC (see TOR 8, Potential for stock mixing).

2. Examine why the resource has declined when the harvest has not exceeded MSY (3,500 mt at the 2008 GARM) since 1984.

Total biomass estimates from 2005 assessment (ASPIC model results), indicated that biomass was highest prior to 1982, the initial year of the VPA.

<u>SARC 52 research recommendations</u>

The following research recommendations are listed in order of priority, by topic, in order to focus on research which will provide the most benefit to improving the stock assessment:

Stock-recruitment relationships

Revise the NEFSC assessment software to include the ability to model S-R functions including environmental factors with errors/probabilities.

Further explore the relationship between large scale environmental forcing (e.g., temperature, circulation, climate) for effects on life history, reproduction, and recruitment in the Georges Bank stock.

Explore development of an index of winter flounder larval abundance based on MARMAP, GLOBEC, etc. time series.

Improvements to landings data

Investigate ways to improve compliance to help VTR reporting. Currently about 300 of the 1500 permitted vessels consistently under-report the number of statistical area fished.

Aging

Investigate the feasibility of port samplers collecting otoliths from large and lemon sole instead of scales because of problems under-ageing larger fish.

Reproduction

Investigate the use of periodic gonad histology studies as a check to make ensure maturity estimates are accurate, with particular attention to obtaining sufficient samples from the Georges Bank stock.

Investigate the skipped spawning percentage for each stock, and estimate interannual variation when sufficient data have been collected.

Fishery-independent surveys

Encourage support for industry-based surveys, which can provide valuable information on stock abundance, distribution, and catchability in research surveys that are independent of and supplemental to NMFS efforts.

Modeling

Explore use of a more complex Stock Synthesis model with small rates of migration between stocks.

Consumption

Develop a time series of winter flounder consumption by the major fish predators of winter flounder.

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Table B1. Proportions of annual Georges Bank winter landings by effort allocation level. "A" level landings represent 1:1 matches between trips in the Vessel Trip Report and Dealer Weighout Databases.

	Allocation Level				
Year	A	B	C	D	Unallocated
1994[1]	0.51	0.21	0.10	0.00	0.18
1995	0.66	0.29	0.05	0.00	0.00
1996	0.65	0.25	0.09	0.00	0.00
1997	0.70	0.18	0.11	0.00	0.00
1998	0.63	0.19	0.17	0.00	0.00
1999	0.70	0.22	0.07	0.00	0.01
2000	0.68	0.23	0.08	0.00	0.01
2001	0.70	0.24	0.04	0.00	0.01
2002	0.66	0.27	0.07	0.00	0.00
2003	0.74	0.18	0.06	0.00	0.02
2004	0.71	0.24	0.05	0.00	0.00
2005	0.78	0.20	0.02	0.00	0.00
2006	0.72	0.18	0.06	0.03	0.00
2007	0.70	0.21	0.08	0.00	0.00
2008	0.74	0.21	0.04	0.00	0.00
2009	0.72	0.24	0.03	0.00	0.00
2010	0.68	0.28	0.04	0.00	0.00

[1] Allocation scheme only applies to May-December of 1994.

Table B2. Proportional standard errors (PSE) for the 1995-2010 landings of Georges bank winter flounder. The PSE (in percent) due to allocation to statistical area using Vessel Trip Reports for 1995 and later years.

Year	Landings (mt)	PSE
1995	783	1.1
1996	1,441	0.9
1997	1,369	1.0
1998	1,401	1.3
1999	1,043	1.2
2000	1,764	1.0
2001	2,203	1.0
2002	2,345	0.7
2003	3,139	0.7
2004	2,851	0.8
2005	2,085	0.7
2006	880	0.8
2007	807	1.0
2008	967	0.8
2009	1,670	0.9
2010	1,297	1.3

Table B3. Landings, discards, and catches (mt) of Georges Bank winter flounder, 1964-2010.

YEAR	522-525 561-562 USA[1]	5Ze[2] (521-526 and 541-562) CA	USSR	5Z (521-562) CA	USSR	TOTAL LANDINGS (mt)	DISCARDS (mt) USA	CA[3]	TOTAL CATCH (mt)
1964	1,370			146		1,516	231		1,747
1965	1,175			199	312	1,686	165		1,851
1966	1,876			164	156	2,196	137		2,333
1967	1,916			83	349	2,348	106		2,454
1968	1,569	57	372			1,998	140		2,138
1969	2,165	116	235			2,516	117		2,633
1970	2,613	61	40			2,714	109		2,824
1971	3,089	62	1,029			4,180	105		4,286
1972	2,802	8	1,699			4,509	98		4,608
1973	2,267	14	693			2,974	94		3,068
1974	2,123	12	82			2,217	98		2,315
1975	2,407	13	515			2,935	118		3,053
1976	1,876	15	1			1,892	142		2,034
1977	3,569	15	7			3,591	207		3,798
1978	3,183	65				3,248	262		3,510
1979	3,042	19				3,061	257		3,319
1980	3,928	44				3,972	255		4,227
1981	3,990	19				4,009	281		4,290
1982	2,959	19				2,978	246	114	3,338
1983	3,894	14				3,908	225	70	4,203
1984	3,927	4				3,931	195	56	4,182
1985	2,151	12				2,163	158	111	2,432
1986	1,761	25				1,786	182	142	2,110
1987	2,637	32				2,669	272	197	3,138
1988	2,804	55				2,859	293	126	3,278
1989	1,880	11				1,891	316	136	2,343
1990	1,898	55				1,953	338	151	2,442
1991	1,814	14				1,828	314	168	2,310
1992	1,822	27				1,849	29	178	2,056
1993	1,662	21				1,683	11	179	1,873
1994	931	65				996	10	145	1,150
1995	729	54				783	1	58	842
1996	1,370	71				1,441	26	87	1,554

Table B3 (cont.)

YEAR	522-525 561-562 USA[1]	5Ze[2] (521-526 and 541-562) CA	USSR	5Z (521-562) CA	USSR	TOTAL LANDINGS (mt)	DISCARDS USA	CA[3] (mt)	TOTAL CATCH (mt)
1997	1,226	143				1,369	69	124	1,562
1998	1,308	93				1,401	52	116	1,569
1999	939	104				1,043	85	107	1,235
2000	1,603	161				1,764	65	198	2,027
2001	1,674	529				2,203	11	199	2,413
2002	2,100	244				2,344	20	193	2,558
2003	2,829	310				3,139	9	179	3,328
2004	2,660	191				2,851	69	105	3,026
2005	2,012	73				2,085	118	145	2,347
2006	825	55				880	110	135	1,125
2007	795	12				807	188	44	1,039
2008	947	20				967	143	69	1,179
2009	1,658	12				1,670	91	252	2,013
2010	1,252	45				1,297	138	109	1,544

[1] USA landings prior to 1985 include those from Statistical Areas 551 and 552, and since May of 1994, landings have been self-reported by dealers and were allocated to statistical areas based on Vessel Trip Report data.
[2] Includes landings from statistical areas 521, 526, and 541 which are outside of the Georges Bank winter flounder stock area.
[3] Only includes discards from CA scallop dredge fleet during 1982-2010; does not include discards from CA bottom trawl fleets.

Table B4. USA landings (mt) of Georges Bank winter flounder, by major gear type, during 1964-2010.

	Landings (mt)				
	Bottom Trawl	Scallop Dredge	Other	Total	% Bottom Trawl
1964	1,359	11.2	0.0	1,370	99.2
1965	1,174	0.9	0.0	1,175	99.9
1966	1,872	4.2	0.0	1,876	99.8
1967	1,914	1.8	0.0	1,916	99.9
1968	1,564	4.6	0.0	1,569	99.7
1969	2,163	1.8	0.0	2,165	99.9
1970	2,609	4.4	0.0	2,613	99.8
1971	3,085	4.8	0.0	3,089	99.8
1972	2,795	7.9	0.0	2,802	99.7
1973	2,264	3.4	0.1	2,267	99.8
1974	2,115	7.7	0.0	2,123	99.6
1975	2,407	0.0	0.0	2,407	100.0
1976	1,875	1.0	0.0	1,876	99.9
1977	3,568	1.1	0.0	3,569	100.0
1978	3,165	17.9	0.0	3,183	99.4
1979	3,018	24.9	0.0	3,042	99.2
1980	3,885	42.5	0.3	3,928	98.9
1981	3,934	53.5	2.5	3,990	98.6
1982	2,917	41.2	0.0	2,959	98.6
1983	3,868	25.4	0.8	3,894	99.3
1984	3,908	18.4	0.4	3,927	99.5
1985	2,148	3.1	0.0	2,151	99.9
1986	1,725	36.0	0.0	1,761	98.0
1987	2,559	77.9	0.0	2,637	97.0
1988	2,697	106.4	0.0	2,804	96.2
1989	1,760	119.7	0.0	1,880	93.6
1990	1,780	118.1	0.1	1,898	93.8
1991	1,673	141.1	0.0	1,814	92.2
1992	1,685	136.3	0.0	1,822	92.5
1993	1,546	115.4	0.0	1,662	93.1
1994	894	21.6	15.3	931	96.0
1995	716	8.5	4.5	729	98.2
1996	1,365	4.6	0.7	1,370	99.6
1997	1,212	12.0	2.0	1,226	98.9
1998	1,293	13.3	1.8	1,308	98.8
1999	925	11.2	2.5	939	98.5
2000	1,577	23.1	3.4	1,603	98.3
2001	1,667	6.3	0.3	1,674	99.6
2002	2,092	1.0	7.1	2,100	99.6
2003	2,826	0.4	3.2	2,829	99.9
2004	2,627	4.5	28.7	2,660	98.8
2005	1,892	111.8	7.8	2,012	94.1
2006	778	21.9	25.8	825	94.2
2007	785	8.8	1.3	795	98.7
2008	944	0.7	2.1	947	99.7
2009	1,656	0.7	2.0	1,658	99.8
2010	1,251	0.1	0.6	1,252	99.9

Table B5. U.S. discards (mt) of Georges Bank winter flounder in the large mesh (codend mesh ≥ 5.5 in.)

and small mesh (codend mesh < 5.5 in.) bottom trawl (BT) fisheries and the scallop dredge fishery during 1964-2010. Discards during 1982-1988, 1964-1988, and 1964-1991 were hindcast for the large and small mesh bottom trawl fisheries and the scallop dredge fishery, respectively.

	U.S. Discards (mt)				
Year	Large mesh BT	Small mesh BT	Scallop dredge	Total	CV
1964		112.1	118.4	230.6	
1965		135.4	29.7	165.1	
1966		118.9	18.2	137.1	
1967		82.0	24.0	106.0	
1968		74.1	65.9	140.0	
1969		74.8	42.2	117.0	
1970		72.6	36.8	109.4	
1971		69.5	35.9	105.4	
1972		61.4	36.7	98.1	
1973		61.1	32.8	94.0	
1974		59.7	38.3	97.9	
1975		60.4	57.6	118.0	
1976		48.8	93.0	141.9	
1977		68.3	138.8	207.0	
1978		77.0	184.9	261.9	
1979		75.8	181.7	257.4	
1980		83.1	171.6	254.7	
1981		97.3	184.0	281.3	
1982	11.4	72.3	162.6	246.3	
1983	39.8	21.8	163.6	225.3	
1984	47.3	3.3	144.5	195.1	
1985	28.9	1.6	127.7	158.2	
1986	23.3	1.6	156.6	181.5	
1987	24.8	1.9	245.5	272.1	
1988	28.3	6.4	258.3	293.0	
1989	13.8	0.1	302.4	316.2	
1990	15.7	0.0	322.3	338.0	
1991	1.9	0.0	311.9	313.8	
1992	8.5	0.0	20.3	28.8	0.22
1993	2.5	0.0	8.1	10.6	0.49
1994	2.3	0.9	6.4	9.5	0.16
1995	1.1	0.0	0.0	1.1	0.56
1996	8.3	0.0	17.4	25.7	0.31
1997	0.0	0.0	69.2	69.2	
1998	0.1	0.0	51.5	51.7	0.01
1999	44.0	0.0	41.2	85.2	0.46
2000	16.7	0.1	48.2	64.9	0.31
2001	2.4	0.0	8.3	10.7	0.15
2002	3.1	0.0	16.5	19.7	0.13
2003	6.5	0.9	2.1	9.5	0.34
2004	46.6	15.4	7.3	69.3	0.48
2005	15.0	15.3	87.5	117.9	0.09
2006	26.3	14.9	68.8	110.0	0.12
2007	50.1	16.0	122.2	188.3	0.23
2008	70.2	0.15	72.6	143.0	0.14
2009	37.5	6.36	46.9	90.8	0.14
2010	29.0	94.2	14.3	137.6	0.44

Table B6. US discards (mt) of Georges Bank winter flounder in the large mesh (codend mesh size ≥ 5.5 in.) and small mesh (codend mesh size < 5.5 in.) bottom trawl fisheries and the scallop dredge/trawl fishery (limited permit category) during 1982-2010. D/K represents discards of GB winter flounder/weight of all species kept. Discards during 1982-1988, 1964-1988, and 1964-1991 were hindcast for the large and small mesh bottom trawl fisheries and the scallop dredge fishery, respectively.

		Large Mesh Bottom Trawl		
YEAR	**N observed trips**	**D/K**	**Discards (mt)**	**CV**
1982			11.4	
1983			39.8	
1984			47.3	
1985			28.9	
1986			23.3	
1987			24.8	
1988			28.3	
1989	17	0.00069	13.8	0.59
1990	13	0.00070	15.7	0.80
1991	13	0.00017	1.9	0.37
1992	16	0.00045	8.5	0.60
1993	17	0.00014	2.5	1.69
1994	22	0.00019	2.3	0.65
1995	37	0.00011	1.1	0.52
1996	13	0.00076	8.3	0.81
1997	6	0.00000	0.0	
1998	5	0.00003	0.1	0.47
1999	7	0.00373	44.0	0.70
2000	17	0.00088	16.7	1.24
2001	26	0.00012	2.4	0.70
2002	48	0.00016	3.1	0.86
2003	107	0.00028	6.5	0.46
2004	154	0.00188	46.6	0.59
2005	569	0.00081	15.0	0.25
2006	303	0.00221	26.3	0.31
2007	304	0.00371	50.1	0.24
2008	397	0.00517	70.2	0.13
2009	342	0.00235	37.5	0.14
2010	311	0.00194	29.0	0.18

Table B6 (cont.)

YEAR	N observed trips	D/K	Discards (mt)	CV
		Small Mesh Bottom Trawl		
1964			112.1	
1965			135.4	
1966			118.9	
1967			82.0	
1968			74.1	
1969			74.8	
1970			72.6	
1971			69.5	
1972			61.4	
1973			61.1	
1974			59.7	
1975			60.4	
1976			48.8	
1977			68.3	
1978			77.0	
1979			75.8	
1980			83.1	
1981			97.3	
1982			72.3	
1983			21.8	
1984			3.3	
1985			1.6	
1986			1.6	
1987			1.9	
1988			6.4	
1989	15	0.00001	0.1	0.87
1990	8	0.00000	0.0	
1991	8	0.00000	0.0	
1992	6	0.00000	0.0	
1993	1	0.00000	0.0	
1994	2	0.01141	0.9	0.00
1995	3	0.00000	0.0	
1996	2	0.00000	0.0	
1997	1	0.00000	0.0	
1998	1	0.00000	0.0	
1999	1	0.00000	0.0	
2000	5	0.00003	0.1	0.97
2001	7	0.00000	0.0	
2002	7	0.00002	0.0	0.82
2003	15	0.00010	0.9	0.85
2004	17	0.00363	15.4	0.89
2005	79	0.00279	15.3	0.64
2006	18	0.00461	14.9	0.77
2007	12	0.00273	16.0	1.38
2008	8	0.00005	0.2	1.33
2009	23	0.00227	6.4	0.62
2010	34	0.02128	94.3	0.63

Table.B6 (cont.)

YEAR	N observed trips	Scallop dredge (Limited category permits) D/K	Discards (mt)	CV
1964			118.4	
1965			29.7	
1966			18.2	
1967			24.0	
1968			65.9	
1969			42.2	
1970			36.8	
1971			35.9	
1972			36.7	
1973			32.8	
1974			38.3	
1975			57.6	
1976			93.0	
1977			138.8	
1978			184.9	
1979			181.7	
1980			171.6	
1981			184.0	
1982			162.6	
1983			163.6	
1984			144.5	
1985			127.7	
1986			156.6	
1987			245.5	
1988			258.3	
1989			302.4	
1990			322.3	
1991			311.9	
1992	6	0.00101	20.3	0.98
1993	8	0.00030	8.1	3.06
1994	5	0.00156	6.4	0.91
1995	3	0.00004	0.0	0.00
1996	54	0.00331	17.4	0.00
1997	6	0.00951	69.2	0.78
1998	4	0.00677	51.5	1.51
1999	19	0.00124	41.2	0.59
2000	179	0.00209	48.2	0.14
2001	16	0.00203	8.3	0.21
2002	4	0.00305	16.5	0.56
2003	2	0.00024	2.1	0.00
2004	30	0.00045	7.3	0.28
2005	62	0.00186	87.5	0.28
2006	68	0.00119	68.8	0.37
2007	59	0.00349	122.2	0.29
2008	42	0.00420	72.6	0.24
2009	58	0.00128	46.9	0.22
2010	8	0.00195	14.3	0.36

Table B7. Numbers of Georges Bank winter flounder sampled for length, by year and market category, and sampling intensity (mt landed per 100 lengths) during 1982-2010.

Year	N lengths by market category					Sampling intensity (mt landed per 100 lengths)
	Unclassified (1200)	Lemon/XL (1201, 1204)	Large/Lg mix (1202, 1205)	Med/small (1203, 1206, 1207)	Total	
1982	350	724	1,019	807	2,900	102
1983		625	1,768	2,100	4,493	87
1984		518	1,435	902	2,855	138
1985	68	728	1,675	1,456	3,927	55
1986	124	389	1,125	1,184	2,822	62
1987		603	1,068	1,437	3,108	85
1988		478	1,034	1,447	2,959	95
1989		167	566	737	1,470	128
1990	399	27	1,285	1,758	3,469	55
1991	103	136	1,603	1,295	3,137	58
1992		131	1,420	1,483	3,034	60
1993		336	509	590	1,435	116
1994		183	632	556	1,371	68
1995		103	279	469	851	86
1996		370	484	138	992	138
1997		43	518	443	1,004	122
1998			79	403	482	271
1999	94		121	274	489	192
2000		486	160	697	1,343	119
2001	102	670	990	804	2,566	65
2002	274	699	1,458	424	2,855	74
2003	268	1,589	2,863	625	5,345	53
2004		1,579	4,643	188	6,410	42
2005	161	1,987	3,790	576	6,514	31
2006	100	1,978	3,196	293	5,567	15
2007		1,659	1,381	161	3,201	25
2008		1,688	2,815	819	5,322	18
2009		2,060	2,383	2,065	6,509	25
2010	456	1,346	3,906	2,686	8,394	15

Table B8. Port sampling of U.S. winter flounder landings from Georges Bank (Statistical Areas 522-525, 551-562), for length and age compositions, during 1982-2010. Total number of samples does not include unclassified market category samples collected in: 1980 (1), 1981 (2), 1982 (4), 1985 (1), 1986 (1), 1990 (4), 1991 (1), 1999 (1), 2001 (1), 2002 (3), 2003 (4), 2005 (3), 2006 (1) and 2010 (5).

				Number of Samples by Market Category and Quarter															Annual Sampling Intensity (mt landed/100 lengths) sample)		
				Lemon Sole: Lemon Sole (1201) Extra-Large (1204)					Large: Large (1202) Large/Mixed (1205)					Small: Small (1203) Medium (1206) Pee-Wee (1207)					1201 1204	1202 1205	1203 1206 1207
Year	N Samples	N Lengths	N Ages	Q1	Q2	Q3	Q4	Tot	Q1	Q2	Q3	Q4	Tot	Q1	Q2	Q3	Q4	Tot	Lemon	Large	Small
1982	26	2,900	739	0	1	6	2	**9**	0	1	6	3	**10**	0	1	5	1	**7**	76	168	69
1983	36	4,493	874	0	3	2	1	**6**	2	5	6	2	**15**	2	3	9	1	**15**	58	100	81
1984	24	2,855	593	0	1	3	1	**5**	3	3	4	3	**13**	1	2	0	3	**6**	73	142	151
1985	38	3,927	827	1	2	5	1	**9**	2	4	9	1	**16**	2	3	7	1	**13**	37	64	50
1986	29	2,822	563	1	1	0	3	**5**	2	3	3	2	**10**	1	6	3	4	**14**	46	66	56
1987	33	3,108	618	2	1	1	2	**6**	4	3	3	1	**11**	5	3	4	4	**16**	40	96	87
1988	34	2,959	693	2	2	1	2	**7**	4	3	3	1	**11**	4	4	4	4	**16**	34	96	103
1989	16	1,470	280	1	1	0	0	**2**	3	2	0	1	**6**	1	3	3	1	**8**	66	127	126
1990	34	3,469	737	0	0	0	1	**1**	3	3	4	3	**13**	6	7	3	4	**20**	265	49	62
1991	35	3,137	698	1	1	1	1	**4**	6	6	2	2	**16**	6	3	3	3	**15**	40	42	72
1992	35	3,034	688	1	2	1	1	**5**	5	4	3	3	**15**	6	5	3	1	**15**	50	47	63
1993	16	1,435	338	1	2	0	1	**4**	3	2	0	0	**5**	1	5	0	1	**7**		125	139

1994	14	1,371	276	0	2	1	0	**4**	1	2	2	1	**6**	1	2	1	1	**5**	33	59	83
1995	9	851	215	1	0	0	1	**2**	1	0	0	2	**3**	2	1	0	1	**4**	43	93	78
1996	10	992	218	0	2	1	1	**4**	0	2	1	1	**4**	0	0	1	1	**2**	18	92	457
1997	13	1,004	232	0	0	0	1	**1**	1	2	1	1	**5**	2	2	0	3	**7**	101	84	81

Table B8 (cont.).

				Number of Samples by Market Category and Quarter															Annual Sampling Intensity (mt landed/100 lengths)		
				Lemon Sole Lemon Sole (1201) Extra-Large (1204)					Large Large (1202) Large/Mixed (1205)					Small Small (1203) Medium (1206) Pee-Wee (1207)					1201 1204	1202 1205	1203 1206 1207
Year	N Samples	N Lengths	N Ages	Q1	Q2	Q3	Q4	Tot	Q1	Q2	Q3	Q4	Tot	Q1	Q2	Q3	Q4	Tot	Lemon	Large	Small
1998	6	482	70	0	0	0	0	**0**	0	1	0	0	**1**	0	1	1	3	**5**	-----	624	193
1999	6	395	78	0	0	0	0	**0**	0	0	0	1	**1**	2	0	0	3	**5**	-----	313	178
2000	17	1,343	283	0	0	1	4	**5**	0	0	0	2	**2**	2	4	1	3	**10**		412	111
2001	27	2,464	606	2	2	1	3	**8**	1	5	3	1	**10**	1	0	2	6	**9**	29	82	73
2002	33	2,485	753	2	4	3	2	**11**	0	9	5	3	**17**	1	1	0	3	**5**	53	81	98
2003	60	4,864	1,396	2	7	4	5	**18**	5	17	8	5	**35**	1	1	0	5	**7**	64	49	52
2004	78	6,343	1,862	1	5	6	5	**17**	6	15	22	13	**56**	1	2	1	1	**5**	37	39	123
2005	75	6,353	1,561	3	9	8	4	**24**	4	17	13	6	**40**	1	4	4	2	**11**	20	35	47

2006	68	5,467	1,458	5	13	4	6	**28**	4	17	9	5	**35**	0	3	1	1	**5**	11	15	35
2007	45	3,201	931	4	7	5	6	**22**	7	7	3	1	**18**	3	0	2	0	**5**	8	35	87
2008	77	5,322	1,463	3	12	7	9	**31**	4	9	9	8	**30**	0	3	9	4	**16**	7	20	30
2009	100	6,508	1,734	4	15	7	15	**41**	2	8	10	4	**24**	3	9	12	11	**35**	4	32	38
2010	135	7,938	2,419	2	14	12	23	**51**	4	20	7	11	**42**	0	20	9	13	**42**	2	11	28

Table B9. Percentage of U.S. landings, during 1982-2010, by market category group.

	% of U.S. Landings by Market Category Group			
	Lemon/XL	Large/LG Mix	Med/Small	Unclassified
Year	1201	1202	1203	1200
1982	18.6	57.9	18.9	4.7
1983	9.3	45.5	43.4	1.8
1984	9.6	51.7	34.8	3.9
1985	12.4	50.1	33.9	3.5
1986	10.1	42.0	37.5	10.4
1987	9.2	38.9	47.4	4.5
1988	5.9	35.5	53.3	5.3
1989	5.9	38.1	49.2	6.7
1990	3.8	33.1	57.3	5.9
1991	3.0	37.5	51.2	8.3
1992	3.6	36.9	51.2	8.3
1993	5.3	38.2	49.3	7.1
1994	6.5	40.3	49.4	3.8
1995	6.1	35.4	50.3	8.2
1996	4.8	32.6	46.1	16.6
1997	3.6	35.5	29.2	31.7
1998	4.0	37.7	56.4	1.9
1999	4.8	40.4	51.8	2.9
2000	7.3	41.1	48.4	3.3
2001	11.4	48.7	34.9	4.9
2002	17.6	56.5	19.8	6.0
2003	35.9	49.3	11.6	3.2
2004	22.3	67.9	8.7	1.2
2005	20.0	65.6	13.4	1.0
2006	25.3	59.4	12.3	3.0
2007	16.9	60.4	17.7	5.1
2008	12.1	59.5	26.0	2.4
2009	5.3	45.8	47.2	1.7
2010	1.9	34.9	60.0	3.3

Table B10. Data pooling procedures used to apply length frequency samples to landings, by market category, to estimate catch-at-age of Georges Bank winter flounder, 1982-2010. An “X” indicates that the time bin applies to all market categories unless otherwise noted.

Year	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Market Category Groups
1982	Pooled each mkt cat		X	X	Pooled 1204 (Extra Large) and 1201 Lemon Sole Pooled 1205 (Large/Mixed) and 1202 (Large) Pooled 1206 (Medium), 1207 (Peewee) and 1203 (Small)
1983	Pooled each mkt cat		X	X	
1984	Pooled each mkt cat		Pooled each mkt cat		
1985	X	X	X	X	
1986	X	X	Pooled each mkt cat		
1987	X	X	X	X	
1988	X	X	X	X	
1989	X	X	Pooled each mkt cat		
1990	X	X	X	X	
1991	X	X	X	X	
1992	X	X	X	X	
1993	X	Pooled each mkt category			
1994	Pooled Lemon/Lg		Pooled Lemon/Lg		Pooled 1201 (Lemon Sole), 1204 (Extra Large), 1202 (Large), and 1205 (Large/Mixed) Pooled 1206 (Medium), 1207 (Peewee) and 1203 (Small)
	X	X	X	X	
1995	Pooled Lemon/Lg		Pooled Lemon/Lg		
	X	X	Pooled Med/Sm		
1996	Pooled Lemon/Lg		X	X	
	Pooled Med/Sm				
1997	X	X	Pooled Lemon/Lg Pooled Med/Sm		
1998	Pooled all mkt categories				Pooled all market categories and included all kept lengths from otter trawl observer trips
1999	Pooled all mkt categories				

Table B10 (cont.).

<table>
<tr><th>Year</th><th>Quarter 1</th><th>Quarter 2</th><th>Quarter 3</th><th>Quarter 4</th><th>Market Category Groups</th></tr>
<tr><td>2000</td><td colspan="2">Pooled all mkt categories</td><td colspan="2">Pooled Lemon/Lg
Pooled Med/Sm</td><td>Pooled market categories as in 1994-1997 and included kept lengths from otter trawl observer trips (months 1-6)</td></tr>
<tr><td>2001</td><td colspan="2">Pooled Med/Sm</td><td>X</td><td>X</td><td rowspan="11">Pooled 1204 (Extra Large) and 1201 Lemon Sole

Pooled 1205 (Large/Mixed) and 1202 (Large)

Pooled 1206 (Medium), 1207 (Peewee) and 1203 (Small)</td></tr>
<tr><td>2002</td><td>X</td><td>X</td><td colspan="2">Pooled Med/Sm</td></tr>
<tr><td>2003</td><td>X</td><td>X</td><td colspan="2">Pooled Med/Sm</td></tr>
<tr><td>2004</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>2005</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>2006</td><td colspan="2">Pooled Med/Sm</td><td>X</td><td>X</td></tr>
<tr><td rowspan="2">2007</td><td colspan="2">Pooled Med/Sm</td><td colspan="2">Pooled Med/Sm</td></tr>
<tr><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>2008</td><td colspan="2">Pooled Med/Sm</td><td>X</td><td>X</td></tr>
<tr><td>2009</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>2010</td><td colspan="2">Pooled Med/Sm</td><td>X</td><td>X</td></tr>
</table>

Table B11. Total landings-at-age (numbers, in thousands) for Georges Bank winter flounder during 1982-2010.

	Age							
Year	1	2	3	4	5	6	7+	Total
1982	0	353	1707	1,048	511	258	281	4,157
1983	10	787	2,902	1,454	551	206	528	6,438
1984	0	282	570	1,371	1,408	635	920	5,186
1985	20	805	693	812	491	112	100	3,031
1986	0	665	1,328	235	229	131	88	2,675
1987	0	1,294	1,681	899	133	89	121	4,217
1988	0	835	2,774	843	197	90	93	4,832
1989	0	1,381	1,222	509	147	107	61	3,427
1990	0	295	2,032	668	185	46	17	3,241
1991	0	593	1,270	951	136	38	60	3,047
1992	0	796	756	727	468	92	61	2,902
1993	37	301	1,143	451	320	163	47	2,461
1994	0	367	635	360	97	50	45	1,554
1995	371	701	172	142	105	32	41	1,563
1996	0	1,319	423	185	95	98	88	2,208
1997	0	355	993	444	176	79	87	2,135
1998	0	10	1,426	826	131	43	12	2,447
1999	0	296	786	521	147	20	20	1,790
2000	0	646	1,108	369	254	186	160	2,723
2001	11	372	1,280	801	586	158	99	3,307
2002	0	121	927	757	445	236	189	2,675
2003	0	259	694	925	455	252	400	2,987
2004	0	62	579	844	520	234	367	2,606
2005	0	224	529	752	362	142	217	2,227
2006	0	25	283	278	122	55	113	876
2007	0	108	135	217	167	73	84	784
2008	0	191	372	303	203	102	95	1,265
2009	0	661	1,089	559	198	92	90	2,689
2010	0	197	867	625	211	74	51	2,025

Table B12. Number of Georges Bank winter flounder lengths sampled by fishery observers from the discards of the bottom trawl and scallop dredge fisheries during 1989-2010.

	N lengths sampled from discards	
Year	Bottom trawl	Scallop dredge
1989	70	0
1990	22	0
1991	5	0
1992	15	1
1993	5	3
1994	6	35
1995	11	0
1996	39	2
1997	1	417
1998	1	84
1999	2	17
2000	4	15
2001	1	0
2002	88	1
2003	92	1
2004	289	125
2005	419	808
2006	423	421
2007	786	889
2008	1,901	636
2009	923	743
2010	704	133

Table B13. Discards-at-age (numbers, in thousands) for Georges Bank winter flounder during 1982-2010.

	Age							
Year	1	2	3	4	5	6	7+	Total
1982	116	706	1,843	1,131	551	278	303	4,928
1983	137	1,051	3,053	1,530	580	217	556	7,123
1984	138	431	595	1,432	1,471	663	961	5,690
1985	67	987	768	899	544	124	111	3,499
1986	38	816	1,522	270	262	150	101	3,159
1987	99	1,556	1,912	1,022	151	101	138	4,980
1988	72	1,049	3,044	925	216	98	102	5,507
1989	34	1,655	1,428	595	172	125	71	4,079
1990	36	392	2,400	789	218	54	20	3,909
1991	2	710	1,505	1,127	161	45	72	3,621
1992	23	842	778	749	482	95	63	3,031
1993	43	317	1,184	467	331	169	49	2,558
1994	8	416	706	400	108	55	51	1,744
1995	394	742	182	149	111	34	43	1,655
1996	35	1,417	450	197	101	104	94	2,397
1997	6	145	74	33	7	2	2	268
1998	0	11	1,561	904	143	47	13	2,680
1999	70	425	887	588	165	22	23	2,180
2000	52	749	1,225	408	281	206	177	3,099
2001	16	410	1,393	872	638	172	108	3,608
2002	0	127	970	793	466	247	198	2,802
2003	0	273	729	972	479	266	421	3,141
2004	4	33	29	39	18	15	18	156
2005	5	42	26	44	26	44	29	217
2006	5	24	52	57	58	11	14	220
2007	23	44	30	41	62	17	13	230
2008	15	135	87	27	24	16	9	313
2009	7	124	145	102	34	22	18	453
2010	3	36	94	79	31	22	22	288

Table B14. Georges Bank winter flounder catch-at-age components.

Catch-at-age component	Years	Time Period	Length data	Age data
U.S. landings	1982-2010		Commercial	Commercial
CA landings	1982-2010		None available, scaled-up the U.S. LAA	None available
U.S. BT discards (lg & sm mesh)				
≤ MLS as discard /mean wt-at-age in NEFSC surveys	1982-2001	Half yr est.	No discard L-F	discard ages unavailable; MLS 1st half yr = age 2 spring and 2nd half yr = age 1 fall
	2002-2010	Half yr est.	U.S. BT discards	NEFSC spring and fall L-W and A/L keys
CA BT discards				
No discard est. provided, assumed zero				
U.S. scallop dredge discards				
	1982-1996 & 1998-2003		No discard L-F; scaled-up LAA	
	1997 & 2004-2010		Annual U.S. scallop dredge discards	NEFSC fall survey L-W and A/L keys
CA scallop dredge discards				
Avg. 2004-2010 rate x annual CA scallop landings	1982-1996 & 1998-2003		None collected by CA ; scaled up LAA	None collected by CA
Estimated by CA DFO	2004-2010		Annual U.S. scallop dredge discards	None collected by CA; 1st half yr = NEFSC spr survey A/L & L-W 2nd half yr = NEFSC spring survey

Table B15. Catch-at-age (numbers, in thousands) for Georges Bank winter flounder during 1982-2010.

	Age							
Year	1	2	3	4	5	6	7+	Total
1982	116	1,058	3,550	2,179	1,061	536	584	9,086
1983	147	1,838	5,954	2,983	1,131	423	1,084	13,561
1984	138	713	1,165	2,803	2,879	1,298	1,880	10,876
1985	87	1,791	1,461	1,711	1,034	235	211	6,530
1986	38	1,481	2,850	505	491	281	189	5,834
1987	99	2,850	3,593	1,921	285	189	259	9,196
1988	72	1,884	5,818	1,767	413	188	196	10,339
1989	34	3,035	2,650	1,104	319	231	131	7,506
1990	36	687	4,431	1,457	402	99	36	7,150
1991	2	1,302	2,775	2,077	297	83	132	6,668
1992	23	1,638	1,534	1,476	950	187	124	5,932
1993	80	617	2,327	918	650	332	95	5,019
1994	8	783	1,341	760	206	105	96	3,298
1995	765	1,443	354	291	217	66	83	3,218
1996	35	2,737	872	381	196	203	182	4,605
1997	6	500	1,068	477	183	81	89	2,403
1998	0	21	2,987	1,730	274	91	26	5,127
1999	70	720	1,673	1,109	312	42	43	3,970
2000	52	1,395	2,333	777	536	392	337	5,823
2001	27	782	2,673	1,673	1,223	330	207	6,915
2002	0	249	1,896	1,551	910	483	387	5,477
2003	0	533	1,423	1,897	934	518	821	6,127
2004	4	95	608	884	537	249	384	2,762
2005	5	266	556	796	388	186	246	2,444
2006	5	49	335	335	181	66	126	1,096
2007	23	152	165	258	230	90	96	1,014
2008	15	325	459	330	226	118	104	1,578
2009	7	786	1,235	662	231	113	107	3,142
2010	3	233	961	704	242	97	73	2,313

Table B16. Mean weights-at-age (kg) in the catches of Georges Bank winter flounder during 1982-2010.

	Age							
Year	1	2	3	4	5	6	7+	All ages
1982	0.216	0.234	0.444	0.779	1.041	1.228	1.615	0.647
1983	0.149	0.260	0.451	0.668	0.899	0.991	1.340	0.576
1984	0.110	0.281	0.467	0.585	0.744	0.891	1.266	0.719
1985	0.191	0.386	0.522	0.782	1.050	1.366	1.720	0.683
1986	0.197	0.392	0.617	0.778	1.029	1.194	1.589	0.650
1987	0.081	0.375	0.549	0.868	1.107	1.217	1.724	0.606
1988	0.145	0.327	0.510	0.760	1.149	1.323	1.761	0.567
1989	0.123	0.355	0.459	0.826	1.076	1.332	1.742	0.538
1990	0.110	0.432	0.510	0.757	0.992	1.339	2.021	0.588
1991	0.190	0.415	0.479	0.702	0.985	1.438	1.751	0.594
1992	0.137	0.386	0.494	0.744	0.906	1.185	1.465	0.627
1993	0.246	0.382	0.537	0.758	0.941	1.294	1.900	0.680
1994	0.200	0.413	0.543	0.803	0.954	1.380	1.618	0.651
1995	0.285	0.387	0.590	0.666	0.999	1.267	1.652	0.501
1996	0.120	0.444	0.649	0.892	1.223	1.467	1.763	0.639
1997	0.000	0.342	0.527	0.691	0.981	1.243	1.440	0.652
1998	0.178	0.244	0.486	0.631	0.809	1.322	1.829	0.572
1999	0.215	0.337	0.452	0.703	1.040	1.569	1.778	0.534
2000	0.119	0.416	0.478	0.568	1.003	1.277	1.627	0.628
2001	0.238	0.306	0.488	0.750	0.827	1.241	1.821	0.664
2002	0.137	0.481	0.554	0.845	1.071	1.340	1.812	0.878
2003	0.124	0.404	0.608	0.968	1.254	1.540	1.893	1.052
2004	0.064	0.449	0.698	0.958	1.214	1.437	1.756	1.096
2005	0.150	0.377	0.588	0.918	1.150	1.419	1.742	0.960
2006	0.093	0.321	0.621	0.883	1.178	1.492	1.873	1.027
2007	0.148	0.337	0.654	0.933	1.181	1.485	1.890	1.023
2008	0.116	0.329	0.550	0.754	0.977	1.195	1.592	0.747
2009	0.047	0.338	0.529	0.752	0.945	1.163	1.578	0.641
2010	0.116	0.339	0.513	0.713	0.893	1.092	1.550	0.666

Table B17. NEFSC spring and fall survey indices from the SRV *Henry B. Bigelow* (HBB) and length-calibrated, equivalent indices for the SRV *Albatross IV* (ALB) time series. Indices are the sum of the stratified mean numbers (n) at length. Spring and fall strata sets include offshore strata 13-23. The length calibration factors are for the Georges Bank stock region for the lengths observed in the calibration experiment (7-61 cm) and include a constant, swept area factor of 0.5505. The effective total catch number calibration factors vary by year and season, depending on the characteristics of the Bigelow length frequency distributions.

Year	Spring (n) HBB	CV	Spring (n) ALB	Effective Factor
2009	8.600	51.9	2.683	3.204
2010	5.063	28.0	2.085	2.428

Year	Autumn (n) HBB	CV	Autumn (n) ALB	Effective Factor
2009	14.220	26.8	6.578	2.162
2010	5.298	36.3	2.380	2.226

Table B18. Relative abundance (stratified mean number per tow) and biomass (stratified mean kg per tow) indices for Georges Bank winter flounder caught in the U.S. spring and autumn (offshore strata 13-23) and Canadian spring (strata 5Z1-5Z4) research vessel bottom trawl surveys. Standardization coefficients for trawl door changes (numbers = 1.46 and weight = 1.39) and gear changes (numbers = 2.02 and weight = 1.86) were applied to NEFSC survey indices.

	U.S. Spring Survey				U.S. Autumn Survey				Canadian Spring Survey	
Year	**Number**	**CV**	**Kg**	**CV**	**Number**	**CV**	**Kg**	**CV**	**Number**	**Kg**
1963					1.94	44.9	3.02	41.0		
1964					1.75	56.4	2.77	51.8		
1965					2.70	36.8	3.03	28.2		
1966					4.79	40.2	5.26	33.7		
1967					1.78	42.3	2.11	35.9		
1968	2.66	51.1	2.99	53.1	1.92	23.1	1.83	28.1		
1969	2.95	20.8	4.02	20.9	2.59	33.2	2.53	32.5		
1970	1.81	21.8	2.20	24.5	7.02	47.3	7.73	47.7		
1971	1.71	20.6	2.04	26.1	1.53	37.5	1.32	36.2		
1972	4.71	34.8	4.90	34.0	1.64	31.4	1.56	27.8		
1973	1.34	36.7	1.73	39.4	2.56	35.9	2.30	33.5		
1974	3.19	33.8	3.16	31.9	1.36	37.7	1.55	42.6		
1975	0.92	37.6	0.72	60.0	3.74	52.3	2.09	34.8		
1976	2.23	27.5	1.57	27.4	5.52	36.7	3.63	40.7		
1977	1.95	43.6	0.90	40.7	4.81	25.0	3.97	22.5		
1978	3.25	35.9	2.52	36.8	4.22	17.9	3.47	17.6		
1979	0.79	26.8	1.09	28.1	5.06	24.8	4.08	23.9		
1980	1.63	43.9	1.45	38.4	2.03	24.8	2.32	25.8		
1981	1.92	35.8	2.00	36.5	5.50	25.3	4.41	20.5		
1982	2.42	29.0	1.57	34.7	5.61	18.6	3.32	20.2		
1983	8.29	35.8	6.93	36.4	3.03	31.9	2.89	35.9		
1984	5.12	27.2	5.22	26.0	4.90	41.5	3.28	40.8		
1985	3.54	43.4	2.44	39.2	1.98	32.8	1.18	32.9		
1986	2.10	34.2	1.26	31.3	3.31	45.0	2.00	43.0		
1987	2.61	30.8	1.16	29.6	0.96	33.6	1.03	42.6	1.24	1.74
1988	2.68	37.5	1.51	33.7	3.90	58.5	1.29	32.1	4.31	2.75
1989	1.25	33.3	0.73	35.9	1.43	45.2	0.96	40.1	4.05	1.95
1990	2.65	47.0	1.48	49.3	0.51	32.7	0.34	37.4	4.93	2.64

1991	2.21	35.0	1.21	28.6	0.31	38.7	0.24	44.0	1.98	1.38
1992	1.34	26.0	0.83	30.5	0.69	35.9	0.38	37.2	0.51	0.59

TableB18. (cont.)

	U.S. Spring Survey				U.S. Autumn Survey				Canadian Spring Survey	
Year	**Number**	**CV**	**Kg**	**CV**	**Number**	**CV**	**Kg**	**CV**	**Number**	**Kg**
1993	1.00	30.1	0.58	25.6	1.22	36.2	0.78	30.9	3.53	1.76
1994	1.25	48.9	0.56	46.9	0.85	34.3	0.56	31.1	5.10	2.01
1995	2.42	37.8	1.38	44.5	2.74	30.3	1.62	28.6	5.63	1.96
1996	2.12	32.7	1.38	28.0	1.48	24.5	1.68	25.1	4.12	2.30
1997	1.48	78.8	1.09	72.5	1.78	20.7	1.55	21.5	4.58	3.09
1998	0.78	34.9	0.71	36.0	3.50	28.1	3.40	30.5	1.14	1.21
1999	3.56	46.2	3.21	50.4	2.45	36.4	2.47	42.0	1.25	1.89
2000	4.25	36.8	3.55	39.2	4.60	57.8	4.82	52.7	1.48	2.22
2001	1.25	38.7	1.16	37.8	6.08	36.6	4.85	31.4	2.28	2.54
2002	4.73	35.6	4.82	32.6	4.67	36.5	5.60	44.2	3.17	3.85
2003	1.22	47.4	1.30	46.2	2.36	38.3	2.96	45.7	1.09	1.31
2004	0.42	33.5	0.51	33.6	5.01	46.3	4.06	44.8	2.10	1.79
2005	1.00	56.8	0.80	64.3	1.94	31.4	2.11	30.9	1.19	1.23
2006	0.58	35.4	0.49	36.9	1.36	28.8	1.42	26.4	0.36	0.39
2007	0.75	29.8	0.68	29.5	2.13	40.1	2.00	50.6	0.18[1]	0.27
2008	7.35	57.8	5.42	66.8	4.58	31.0	2.70	25.5	1.07	0.65
2009	2.68	51.9	1.36	42.1	6.58	26.8	5.20	29.0	0.70	0.56
2010	2.09	28.0	1.36	26.1	2.38[2]	36.3	1.83	36.7	0.79	0.66
Median	2.11		1.42		2.56[4]		2.32		1.98	1.79

[1] No tows conducted in the northwest portion of stratum 5Z3 due to adverse weather conditions.
[2] One station in each of strata 16 and 19 were not sampled due to vessel problems.
[3] For U.S. survey indices from 2009 onward, length-based conversion factors were applied to SRV *H. B. Bigelow* numbers-at-length to obtain SRV *Albatross* IV equivalents and kg per tow were computed by applying the respective seasonal survey length-weight equations
[4] There were no stations sampled on the Canadian side of Georges Bank, during fall 2010, due to severe weather delays during previous survey legs.

Table B19. NEFSC fall survey minimum population sizes-at-age (thous. of fish) for Georges Bank winter flounder (offshore strata 13-23).

Numbers at age include data for 1981-2010 lagged forward one year and age.

	Age										
Year	1	2	3	4	5	6	7	8	9	10+	Total
1982	0	2,396	674	814	1,082	504	135	244	147	63	6,059
1983	284	2,094	2,178	583	542	283	184	0	33	0	6,181
1984	27	70	568	1,347	619	236	264	95	57	57	3,339
1985	239	654	1,189	1,391	1,408	368	113	26	12	0	5,401
1986	110	341	885	550	80	190	27	0	0	0	2,182
1987	145	1,160	1,627	370	205	48	24	23	0	48	3,652
1988	36	53	239	256	208	99	80	62	27	0	1,061
1989	49	2,958	620	468	139	9	25	25	0	0	4,293
1990	24	97	1,072	73	143	74	58	9	27	0	1,577
1991	24	61	44	376	0	52	0	0	0	0	557
1992	109	46	0	81	53	18	36	0	0	0	344
1993	0	53	509	158	9	27	0	0	0	0	757
1994	0	592	192	283	213	27	0	18	0	18	1,343
1995	0	167	424	224	86	33	0	0	0	0	934
1996	18	937	1,115	685	187	57	0	0	18	0	3,018
1997	0	124	344	614	259	131	94	63	0	0	1,628
1998	18	79	648	758	344	79	30	3	0	0	1,960
1999	91	273	386	1,713	1,109	190	66	27	0	0	3,854
2000	18	388	796	381	367	608	88	27	24	0	2,697
2001	18	53	1,286	1,666	753	902	270	56	69	0	5,073
2002	18	599	1,536	2,442	1,276	322	332	100	53	25	6,703
2003	0	206	496	1,053	1,309	1,148	410	477	23	23	5,146
2004	309	176	27	352	770	652	209	80	21	0	2,597
2005	231	326	1,353	1,377	1,328	282	349	230	44	0	5,520
2006	97	55	167	493	464	297	358	132	18	58	2,139
2007	0	101	179	307	380	422	72	42	0	0	1,502
2008	231	313	317	307	428	613	91	34	18	0	2,351
2009	90	1,152	1,612	1,202	286	346	224	48	0	88	5,047
2010	0	190	1,509	2,401	1,882	665	363	72	46	121	7,249
2011	38	31	487	941	696	211	134	28	15	42	2,623

Table B20. NEFSC spring survey minimum population sizes-at-age (thous. of fish) for Georges Bank winter flounder (offshore strata 13-23) during 1982-2010.

Year	Age 1	2	3	4	5	6	7	8	9	10+	Total
1982	74	903	555	660	191	151	41	18	36	36	2,665
1983	27	1,037	3,704	1,555	692	796	608	424	125	169	9,135
1984	36	168	2,107	1,635	390	379	477	280	27	146	5,644
1985	0	1,701	821	636	402	223	47	24	49	0	3,902
1986	255	752	857	192	170	85	0	0	0	0	2,310
1987	163	1,647	670	275	91	0	24	0	0	0	2,871
1988	73	556	1,433	692	117	42	18	0	27	0	2,958
1989	49	560	293	251	157	18	0	53	0	0	1,381
1990	129	653	1,611	357	99	74	0	0	0	0	2,923
1991	273	349	834	587	278	36	24	0	49	0	2,430
1992	73	652	302	141	148	111	0	24	27	0	1,477
1993	172	291	362	175	0	47	33	24	0	0	1,105
1994	127	604	436	96	66	45	0	0	0	0	1,374
1995	150	790	1,295	297	103	30	0	0	0	0	2,664
1996	38	1,233	436	494	70	27	43	0	0	0	2,339
1997	24	194	542	677	115	24	27	0	24	0	1,627
1998	0	24	218	468	125	0	27	0	0	0	861
1999	225	548	675	1,313	896	200	53	18	0	0	3,927
2000	18	620	1,069	697	1,155	734	200	120	71	0	4,685
2001	0	73	335	314	197	193	268	0	0	0	1,380
2002	113	167	245	1,935	772	784	701	312	159	26	5,215
2003	52	27	163	231	367	320	154	27	0	0	1,341
2004	0	36	27	63	215	73	24	28	0	0	465
2005	98	188	130	315	212	132	0	27	0	0	1,101
2006	43	0	188	210	88	81	0	24	0	0	634
2007	91	128	67	159	180	100	56	23	19	0	822
2008	945	1,280	1,513	1,945	1,427	386	94	504	0	0	8,094
2009	0	43	1,258	831	456	161	145	22	28	13	2,957
2010	0	7	153	901	693	242	230	25	18	15	2,285

Table B21. Canadian spring (February) survey minimum population sizes-at-age (thous. of fish) for Georges Bank winter flounder during 1987-2010.

	Age										
Year	1	2	3	4	5	6	7	8	9	10+	Total
1987	0	68	153	202	255	102	0	0	0	0	780
1988	102	386	1,396	653	101	46	0	23	0	0	2,708
1989	54	1,244	623	448	141	27	4	6	0	0	2,547
1990	0	88	683	1,991	262	42	25	3	0	0	3,094
1991	44	57	412	577	129	29	0	0	0	0	1,247
1992	0	17	38	131	48	86	0	3	0	0	323
1993	746	419	595	282	85	48	41	3	0	0	2,219
1994	10	2,083	705	155	234	1	11	10	0	0	3,207
1995	992	1,544	799	134	57	8	2	0	0	0	3,534
1996	562	792	589	408	136	50	48	2	3	4	2,594
1997	11	609	990	1,102	120	23	9	17	0	0	2,880
1998	11	19	100	382	180	21	0	0	0	0	714
1999	32	154	146	252	145	36	12	4	4	0	784
2000	6	0	7	87	82	227	227	120	121	54	932
2001	150	49	121	147	276	92	232	348	10	11	1,437
2002	0	58	136	51	729	256	270	284	126	83	1,993
2003	29	135	37	53	80	131	86	126	7	2	686
2004	331	113	59	138	136	327	101	96	17	0	1,319
2005	55	100	55	104	107	107	102	63	37	17	748
2006	0	3	3	50	62	33	68	2	3	1	226
2007	0	0	3	0	8	39	24	21	8	9	112
2008	260	123	48	54	75	26	32	54	0	0	671
2009	11	75	184	68	25	35	5	21	0	16	439
2010	0	44	204	141	65	19	0	24	0	0	497

Table B22. Input data and descriptions of the VPA model runs conducted for the SARC 52 assessment of Georges Bank winter flounder. All model runs included catch-at-age data for 1982-2010 for ages 1-7+.

Run	Description	Catch-at-age	Tuning Indices (swept area nos.)	M	Maturity	2011 stock estimates	R in 2011	Avg F	Recruits	Selectivity
2008 GARM update	US BT and scallop dredge (SD) discards; US landings bumped up by CA landings	US BT and scallop dredge (SD) discards; US landings bumped up by CA landings, ages 1-7+	US spr & CA spr svys, ages 1-7+ US fall svy, ages 0-6 (lagged forward 1 yr and age)	0.2	1982-2007 mean (0.08, 0.54, 0.94, 1.0,1.0,1.0,1.0)	Ages 2-6, but age 2 CV = 1	Geom. Mean, 2003-2009	Ages 4-6	Age 1	Flat-topped, full at age 4
Run 4	New maturity schedule and addition of CA SD discards	Same as above plus CA SD discards	Same as above (denoted as "S")	0.2	1981-2010, 3-yr moving window[1]	Ages 3-6	S	S	S	S
Run 5 (Final Run)	Same as Run 4, but M = 0.3			0.3						
Sensitivity Run 1	Same as Run5, but with maturity schedule from 2008 GARM									
Sensitivity Run 2	Same as Run 5, but no CA svy									
Sensitivity Run 3	Same as Run 5, CA svy downwtd to 0.42									

[1] Based on histological study results; fully mature at age 4

Table B23. Summarization of retrospective relative errors (percent) in F and SSB for ADAPT VPA Final Run 5 and Sensitivity Runs 2 and 3. The smallest error ranges are highlighted in bold.

Model Run	% Error F	% Error SSB
Final Run 5	**-48 to +42**	**-13 to +43**
Sensitivity Run 2 (no CA surveys)	-61 to +44	-14 to +85
Sensitivity Run 3 (CA surveys down-weighted to 0.42)	-58 to +38	-14 to +75

Table B24. VPA estimates of January 1 stock sizes (nos. in 000's), by year and age, for Georges Bank winter flounder during 1982-2010.

AGE	1982	1983	1984	1985	1986
1	13764.	8338.	17881.	16791.	21914.
2	21622.	10097.	6051.	13129.	12365.
3	15683.	15112.	5913.	3873.	8197.
4	8440.	8597.	6164.	3388.	1634.
5	3016.	4400.	3842.	2206.	1073.
6	1897.	1336.	2298.	479.	764.
7	2066.	3426.	3329.	430.	515.
Total	66488.	51305.	45478.	40296.	46461.

AGE	1987	1988	1989	1990	1991
1	15543.	26317.	14913.	9881.	13239.
2	16202.	11429.	19435.	11019.	7289.
3	7895.	9572.	6860.	11808.	7575.
4	3659.	2822.	2240.	2842.	5000.
5	782.	1099.	619.	731.	882.
6	382.	339.	465.	191.	205.
7	521.	353.	263.	70.	327.
Total	44983.	51931.	44795.	36541.	34517.

AGE	1992	1993	1994	1995	1996
1	6424.	5205.	7314.	22836.	16323.
2	9806.	4739.	3787.	5412.	16262.
3	4290.	5867.	2984.	2139.	2783.
4	3263.	1879.	2381.	1081.	1283.
5	1951.	1174.	621.	1119.	553.
6	402.	647.	325.	286.	644.
7	267.	186.	299.	361.	578.
Total	26403.	19698.	17711.	33233.	38426.

AGE	1997	1998	1999	2000	2001
1	16273.	18754.	18351.	14432.	8975.
2	12062.	12053.	13892.	13535.	10646.
3	9713.	8587.	8912.	9675.	8834.
4	1322.	6324.	3832.	5176.	5183.
5	627.	593.	3215.	1897.	3171.
6	244.	313.	209.	2115.	951.
7	268.	88.	213.	1819.	596.
Total	40509.	46712.	48623.	48648.	38356.

AGE	2002	2003	2004	2005	2006
1	7279.	6063.	5520.	5555.	10493.
2	6625.	5392.	4491.	4087.	4111.
3	7218.	4695.	3539.	3252.	2800.
4	4277.	3736.	2270.	2115.	1942.
5	2421.	1856.	1175.	954.	914.
6	1315.	1023.	590.	428.	391.
7	1053.	1622.	931.	613.	776.
Total	30189.	24387.	18516.	17004.	21429.

AGE	2007	2008	2009	2010	2011
1	15577.	18849.	4032.	22530.	8111.
2	7770.	11520.	13952.	2981.	16688.
3	3014.	5626.	8256.	9663.	2009.
4	1813.	2092.	3775.	5062.	6337.
5	1182.	1122.	1268.	2232.	3149.
6	553.	680.	639.	742.	1447.
7	591.	603.	607.	589.	845.
Total	30499.	40493.	32528.	43800.	38586.

Table B25. VPA estimates of average fishing mortality rates (ages 4-6), by year and age, for Georges Bank winter flounder during 1982-2010.

AGE	1982	1983	1984	1985	1986
1	0.0098	0.0206	0.0090	0.0060	0.0020
2	0.0582	0.2351	0.1461	0.1711	0.1486
3	0.3012	0.5967	0.2570	0.5630	0.5066
4	0.3513	0.5053	0.7276	0.8498	0.4366
5	0.5145	0.3495	1.7824	0.7607	0.7338
6	0.3918	0.4498	1.0156	0.8137	0.5441
7	0.3918	0.4498	1.0156	0.8137	0.5441
Avg	0.4192	0.4349	1.1752	0.8081	0.5715

AGE	1987	1988	1989	1990	1991
1	0.0074	0.0032	0.0027	0.0042	0.0002
2	0.2262	0.2105	0.1983	0.0748	0.2302
3	0.7288	1.1525	0.5811	0.5593	0.5420
4	0.9026	1.2172	0.8195	0.8699	0.6412
5	0.5373	0.5609	0.8777	0.9731	0.4855
6	0.8278	0.9861	0.8318	0.8901	0.6162
7	0.8278	0.9861	0.8318	0.8901	0.6162
Avg	0.7559	0.9214	0.8430	0.9110	0.5810

AGE	1992	1993	1994	1995	1996
1	0.0041	0.0179	0.0012	0.0395	0.0025
2	0.2136	0.1626	0.2713	0.3650	0.2154
3	0.5253	0.6020	0.7156	0.2111	0.4445
4	0.7221	0.8075	0.4549	0.3692	0.4162
5	0.8042	0.9835	0.4764	0.2520	0.5183
6	0.7520	0.8715	0.4593	0.3079	0.4459
7	0.7520	0.8715	0.4593	0.3079	0.4459
Avg	0.7594	0.8875	0.4635	0.3097	0.4601

AGE	1997	1998	1999	2000	2001
1	0.0001	0.0001	0.0044	0.0042	0.0035
2	0.0398	0.0020	0.0618	0.1267	0.0886
3	0.1292	0.5068	0.2434	0.3242	0.4254
4	0.5012	0.3765	0.4030	0.1898	0.4612
5	0.3959	0.7427	0.1189	0.3910	0.5801
6	0.4661	0.4031	0.2633	0.2399	0.5047
7	0.4661	0.4031	0.2633	0.2399	0.5047
Avg	0.4544	0.5074	0.2617	0.2736	0.5154

AGE	2002	2003	2004	2005	2006
1	0.0001	0.0001	0.0006	0.0009	0.0004
2	0.0444	0.1211	0.0227	0.0780	0.0105
3	0.3587	0.4266	0.2148	0.2156	0.1349
4	0.5347	0.8570	0.5673	0.5386	0.1970
5	0.5609	0.8453	0.7096	0.5915	0.2037
6	0.5441	0.8531	0.6136	0.5547	0.1991
7	0.5441	0.8531	0.6136	0.5547	0.1991
Avg	0.5466	0.8518	0.6302	0.5616	0.1999

AGE	2007	2008	2009	2010
1	0.0017	0.0009	0.0021	0.0002
2	0.0230	0.0332	0.0673	0.0948
3	0.0652	0.0990	0.1891	0.1219
4	0.1793	0.2005	0.2253	0.1747
5	0.2530	0.2637	0.2356	0.1336
6	0.2077	0.2221	0.2279	0.1541
7	0.2077	0.2221	0.2279	0.1541
Avg	0.2133	0.2288	0.2296	0.1541

Table B26. VPA estimates of spawning stock biomass (mt), by year and age, for Georges Bank winter flounder during 1982-2010.

AGE	1982	1983	1984	1985	1986
1	53.	20.	0.	0.	34.
2	707.	438.	143.	593.	1086.
3	4057.	3698.	1639.	1396.	3566.
4	5282.	4155.	2587.	1747.	957.
5	2593.	3245.	1653.	1535.	796.
6	1881.	1111.	1477.	425.	715.
7	2807.	3806.	3033.	560.	663.
Total	17380.	16474.	10533.	6256.	7817.

AGE	1987	1988	1989	1990	1991
1	8.	28.	0.	0.	0.
2	1270.	603.	487.	253.	228.
3	2988.	2987.	2321.	4437.	2664.
4	2159.	1353.	1240.	1417.	2561.
5	643.	949.	455.	504.	669.
6	336.	311.	450.	179.	213.
7	678.	450.	346.	105.	456.
Total	8082.	6682.	5298.	6896.	6791.

AGE	1992	1993	1994	1995	1996
1	0.	0.	0.	0.	0.
2	474.	175.	0.	105.	511.
3	1519.	2107.	1151.	1016.	1318.
4	1685.	970.	1432.	579.	863.
5	1258.	756.	461.	922.	474.
6	350.	571.	337.	290.	713.
7	301.	264.	400.	512.	845.
Total	5587.	4843.	3780.	3424.	4724.

AGE	1997	1998	1999	2000	2001
1	0.	0.	0.	0.	0.
2	490.	24.	1458.	1416.	677.
3	4567.	3320.	3014.	3625.	3455.
4	761.	3260.	2061.	2457.	2871.
5	512.	359.	2658.	1465.	1916.
6	249.	323.	242.	2242.	915.
7	322.	135.	328.	2585.	888.
Total	6901.	7421.	9760.	13790.	10722.

AGE	2002	2003	2004	2005	2006
1	0.	0.	0.	0.	0.
2	25.	15.	0.	0.	330.
3	2895.	2155.	917.	1592.	1423.
4	2557.	2355.	1574.	1497.	1435.
5	1912.	1584.	1053.	852.	946.
6	1265.	1079.	659.	492.	504.
7	1546.	2302.	1307.	872.	1305.
Total	10199.	9489.	5509.	5304.	5943.

AGE	2007	2008	2009	2010
1	0.	0.	0.	0.
2	187.	186.	112.	28.
3	1717.	2336.	2911.	3352.
4	1398.	1383.	2356.	3038.
5	1207.	964.	1020.	1727.
6	717.	722.	654.	729.
7	1003.	866.	864.	830.
Total	6228.	6457.	7916.	9703.

Table B27. Summary of final VPA model of average fishing mortality and spawning stock biomass, during 1982-2010, and age 1 recruitment, during 1982-2011, for Georges Bank winter flounder.

Year	Average F (ages 4-6)	Spawning Stock Biomass (mt)	Recruitment (numbers in 000's)
1982	0.419	17,380	13,764
1983	0.435	16,473	8,338
1984	1.175	10,532	17,881
1985	0.808	6,256	16,791
1986	0.572	7,817	21,914
1987	0.756	8,082	15,543
1988	0.921	6,681	26,317
1989	0.843	5,299	14,913
1990	0.911	6,895	9,881
1991	0.581	6,791	13,239
1992	0.759	5,587	6,424
1993	0.888	4,843	5,205
1994	0.464	3,781	7,314
1995	0.310	3,424	22,836
1996	0.460	4,724	16,323
1997	0.454	6,901	16,273
1998	0.507	7,421	18,754
1999	0.262	9,761	18,351
2000	0.274	13,790	14,432
2001	0.515	10,722	8,975
2002	0.547	10,200	7,279
2003	0.852	9,490	6,063
2004	0.630	5,510	5,520
2005	0.562	5,305	5,555
2006	0.200	5,943	10,493
2007	0.213	6,229	15,577
2008	0.229	6,457	18,849
2009	0.230	7,917	4,032
2010	0.154	9,703	22,530
2011			8,111

Table B28. Bootstrapped estimates of the 2011 stock sizes-at-age, from the final VPA run, and the associated precision and bias estimates for Georges Bank winter flounder during 1982-2010.

	NLLS Estimate	Bootstrap Mean	Bootstrap Std Error	C.V. For NLLS Soln.
N 3	2009.	2412.	1518.	0.6296
N 4	6337.	7087.	3420.	0.4826
N 5	3149.	3324.	1153.	0.3468
N 6	1447.	1476.	451.	0.3057

	Bias Estimate	Bias Std. Error	Per Cent Bias	NLLS Estimate Corrected For Bias	C.V. For Corrected Estimate
N 3	403.	50.	20.0552	1606.	0.9454
N 4	751.	111.	11.8451	5586.	0.6123
N 5	175.	37.	5.5653	2974.	0.3877
N 6	29.	14.	1.9959	1418.	0.3181

	LOWER 80. % CI	UPPER 80. % CI
N 3	933.	4470.
N 4	3435.	11267.
N 5	1986.	4849.
N 6	906.	2080.

Table B29. Bootstrapped estimates of the 2010 fishing mortality rates-at-age, from the final VPA run, and the associated precision and bias estimates for Georges Bank winter flounder during 1982-2010.

	NLLS Estimate	Bootstrap Mean	Bootstrap Std Error	C.V. For NLLS Soln.
AGE 1	0.0002	0.0002	0.000036	0.2193
AGE 2	0.0948	0.1116	0.073437	0.6580
AGE 3	0.1219	0.1329	0.061768	0.4647
AGE 4	0.1747	0.1847	0.064397	0.3487
AGE 5	0.1336	0.1434	0.047338	0.3300
AGE 6	0.1541	0.1641	0.035979	0.2193
AGE 7	0.1541	0.1641	0.035979	0.2193

	Bias Estimate	Bias Std. Error	Per Cent Bias	NLLS Estimate Corrected For Bias	C.V. For Corrected Estimate
AGE 1	0.000010	0.000001	6.4324	0.0001	0.2495
AGE 2	0.016849	0.002383	17.7799	0.0779	0.9425
AGE 3	0.011008	0.001984	9.0293	0.1109	0.5569
AGE 4	0.009999	0.002061	5.7242	0.1647	0.3910
AGE 5	0.009831	0.001529	7.3583	0.1238	0.3825
AGE 6	0.009915	0.001180	6.4324	0.1442	0.2495
AGE 7	0.009915	0.001180	6.4324	0.1442	0.2495

	LOWER 80. % CI	UPPER 80. % CI
AGE 1	0.000124	0.000211
AGE 2	0.043715	0.191725
AGE 3	0.070101	0.213764
AGE 4	0.117007	0.263409
AGE 5	0.094499	0.203220
AGE 6	0.123687	0.211153
AGE 7	0.123687	0.211153

Table B30. Georges Bank winter flounder catches (mt) and proportional standard errors (PSE, shown as a %), 1982-2010. Annual Canadian landings and discards were assumed to have the same PSEs as the U.S. landings and discards.

Year	Landings	PSE 1995-2010	Discards	PSE 1995-2010	Catch	Weighted PSE
1982	2,978	0.9	360	26	3,338	3.6
1983	3,908	0.9	295	26	4,203	2.7
1984	3,931	0.9	251	26	4,182	2.4
1985	2,163	0.9	269	26	2,432	3.7
1986	1,786	0.9	324	26	2,110	4.7
1987	2,669	0.9	469	26	3,138	4.7
1988	2,859	0.9	419	26	3,278	4.1
1989	1,891	0.9	452	26	2,343	5.7
1990	1,953	0.9	489	26	2,442	5.9
1991	1,828	0.9	482	26	2,310	6.1
1992	1,849	0.9	207	26	2,056	3.4
1993	1,683	0.9	190	26	1,873	3.4
1994	996	0.9	155	26	1,150	4.3
1995	783	1.1	59	56	842	4.9
1996	1,441	0.9	113	31	1,554	3.1
1997	1,369	1.0	193	--	1,562	--
1998	1,401	1.3	167	1	1,569	1.2
1999	1,043	1.2	192	46	1,235	8.2
2000	1,764	1.0	263	31	2,027	4.9
2001	2,203	1.0	210	15	2,413	2.2
2002	2,345	0.7	213	13	2,558	1.8
2003	3,139	0.7	189	34	3,328	2.6
2004	2,851	0.8	174	48	3,026	3.5
2005	2,085	0.7	263	9	2,347	1.6
2006	880	0.8	245	12	1,125	3.2
2007	807	1.0	232	23	1,039	5.9
2008	967	0.8	212	14	1,179	3.2
2009	1,670	0.9	343	14	2,013	3.2
2010	1,297	1.3	247	44	1,544	8.1
Mean	1,950	0.9	265	26	2,214	4.0

Table B31. Input data to a per-recruit model and projection software for Georges Bank winter flounder. The data represent the most recent five-year averages, 2006-2010, from the final VPA model.

Age	Selectivity on F	Selectivity on M	Stock weights	Catch weights	Spawning stock weights	Proportion mature
1	0.005	1	0.187	0.182	0.179	0.00
2	0.221	1	0.233	0.377	0.297	0.09
3	0.590	1	0.481	0.602	0.538	0.90
4	1.000	1	0.713	0.829	0.768	1.00
5	1.000	1	0.970	1.080	1.023	1.00
6	1.000	1	1.230	1.338	1.282	1.00
7+	1.000	1	1.734	1.734	1.734	1.00

Table B32. Summary of Beverton-Holt stock-recruitment model fits for Georges Bank winter flounder based on input data from the final VPA model (Run 5) for the 1982-2009 year classes. The candidate FMSY reference point (= 0.42) was estimated from the model run with steepness (*h*) fixed at 0.78. Note that the only FMSY estimate from this model was used as a biological reference point.

			Final Model
	No prior	Prior on *h*[1]	Fixed *h*[2]
FMSY	1.2	0.50	0.42
SSBMSY (mt)	3,690	7,891	9,524
MSY (mt)	3,801	3,679	3,757
Fmax	1.2	1.2	1.2
h	1.00	0.85	0.78
R_0	13,584	15,710	17,337
NegLL	284.354	283.624	279.484
AIC	575.707	576.927	577.945

[1] Steepness prior (*h*) set to 0.80 and SE set to 0.09 based on values for Pleuronectids reported in Myers et al. (1999)

[2] See text for rationale behind fixing *h* at 0.78

Table B33. Log-likelihood profile for unfished steepness (*h*) values from Beverton-Holt stock-recruitment models for Georges Bank winter flounder that included the 1982-2009 year-classes.

Unfished steepness (*h*)	F_{MSY}	SSBMSY (mt)	MSY (mt)	Bias-corrected AIC	NLL
0.60	0.26	19,785	4,910	583.217	282.120
0.65	0.30	15,144	4,318	581.230	281.126
0.70	0.34	12,437	4,003	579.698	280.361
0.75	0.38	10,673	3,824	578.518	279.770
0.76	0.39	10,341	3,799	578.317	279.670
0.77	0.41	9,798	3,777	578.126	279.574
0.78	0.42	9,524	3,757	577.945	279.484
0.79	0.43	9,269	3,740	577.774	279.398
0.80	0.44	9,030	3,725	577.611	279.317
0.85	0.51	7,742	3,678	576.917	278.970
0.90	0.60	6,621	3,672	576.390	278.706
0.95	0.74	5,476	3,706	575.996	278.509

Table B34. Existing and candidate biological reference points (BRPs), and 80% confidence intervals(shown in parentheses), which were presented to the SARC 52 Review Panel. Note that the Candidate BRPs in this table were revised by the SARC 52 Review Panel.

BRP type	Estimation Method	$F_{40\%}$	$SSB_{40\%}$ (mt)	$MSY_{40\%}$ (mt)	F_{MSY}	SSB_{MSY} (mt)	MSY (mt)
Candidate[1]	Stochastic projection (100 yr) of F40% estimate from a per-recruit model	0.32	11,300 (8,600, 4,000)	3,200 (2,500,4,000)			
Candidate[2]	Stochastic projection (100 yr) of FMSY estimate from Beverton-Holt model				0.50	8,300 (5,800, 12,000)	4,200 (3,000, 5,900)
Existing	Stochastic projection (100 yr) of F40% estimate from a per-recruit model	0.26	16,000 (12,800, 9,200)	3,500 (2,800, 4,300)			

[1] Not directly comparable to existing BRPs due to an increase in M, from 0.2 to 0.3, and other changes in model input data

[2] Steepness prior (*h*) = 0.80 and SE = 0.09 based on values for Pleuronectids reported in Myers et al. (1999)

Table B35. Biological reference points and 2010 F and SSB estimates (and 80% confidence limits) used to determine stock status of Georges Bank winter flounder during 2010.

FMSY[1]	0.42
SSBMSY (mt)	11,800 (8,500, 16,800)
MSY (mt)	4,400 (3,200, 6,100)
F2010	0.154 (0.121, 0.207)
SSB2010 (mt)	9,703 (7,304, 12,578)

[1] Precision estimates were not possible because the steepness parameter (*h*) was fixed at 0.78

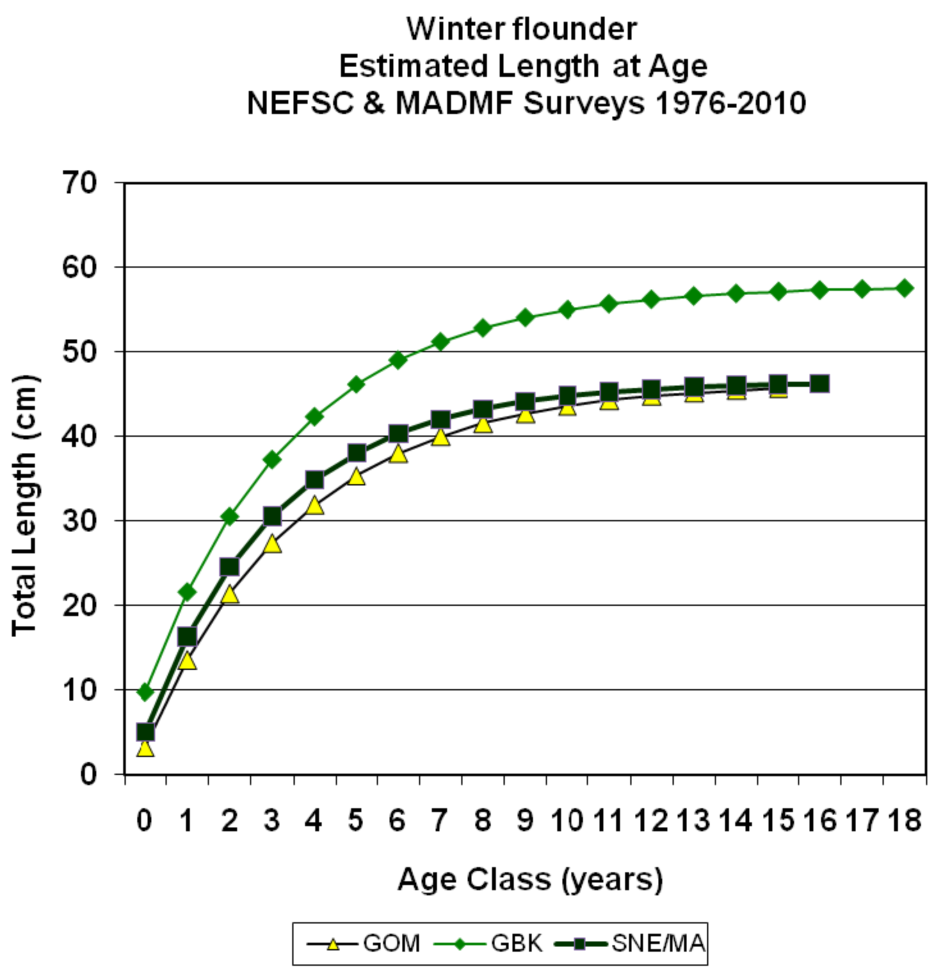


Figure B1. Comparison of estimated growth curves (von Bertalanffy growth) for winter flounder from the SNE/MA and Gulf of Maine stocks (based on MA DMF spring survey data) and the Georges Bank stock (based on NEFSC spring survey data).

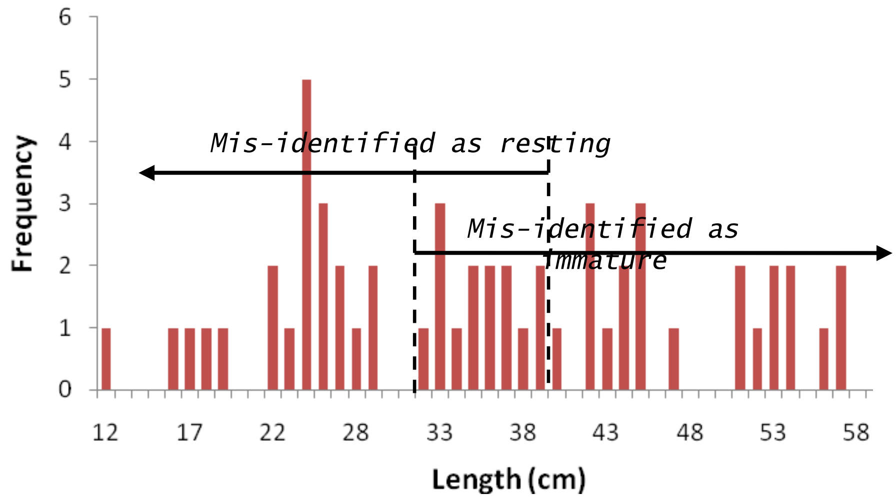


Figure B2. Length composition of Georges Bank winter flounder samples from a histology study which indicated that individuals < 38 cm were mis-identified as resting fish and individuals > 30 cm were mis-identified as immature fish.

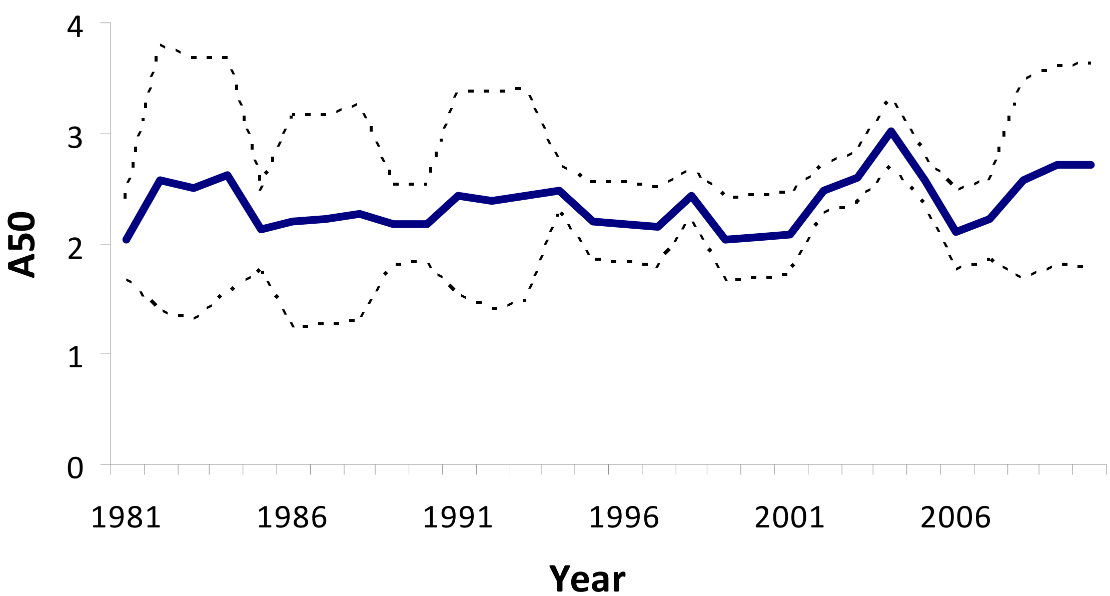


Figure B3. Three-year moving window (NEFSC spring surveys during 1981-2010) of female A50 values (age at 50% maturity) for Georges Bank winter flounder

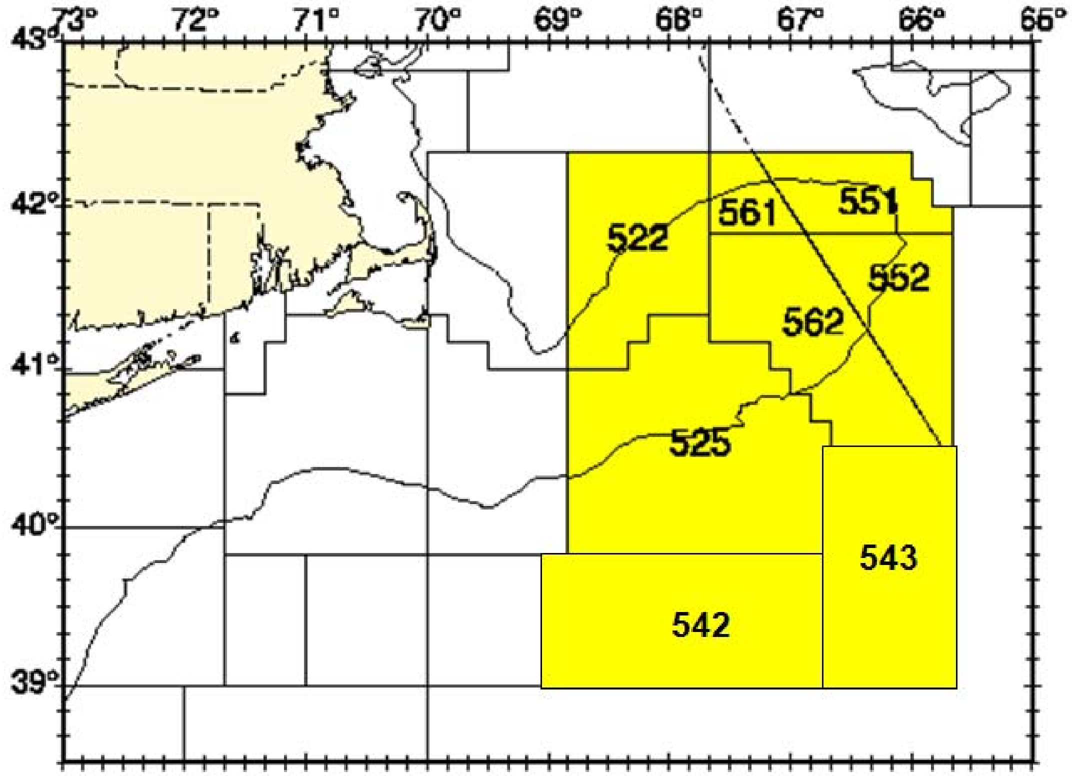


Figure B4. Statistical Areas used for reporting fishery data for the Georges Bank winter flounder stock.

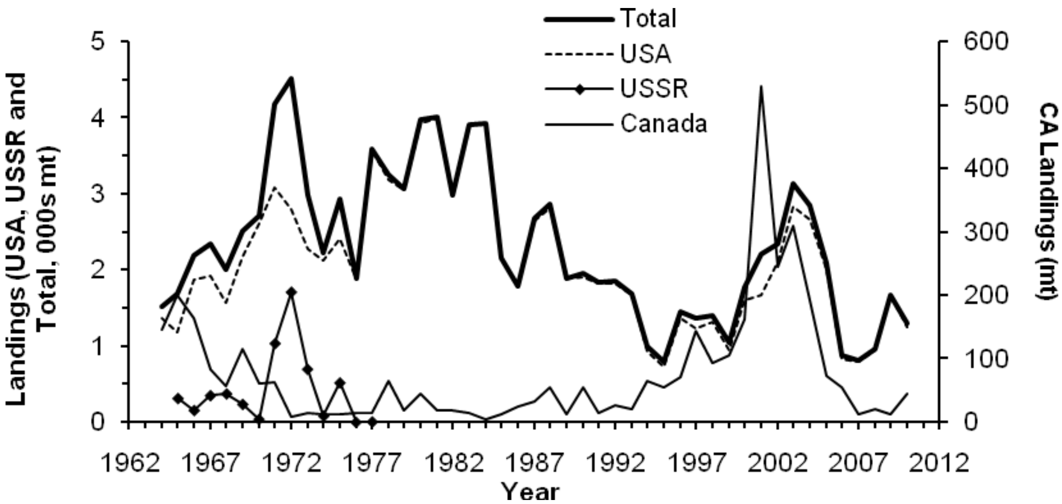


Figure B5. Landings (mt) of Georges Bank winter flounder, by country, during 1964-2010.

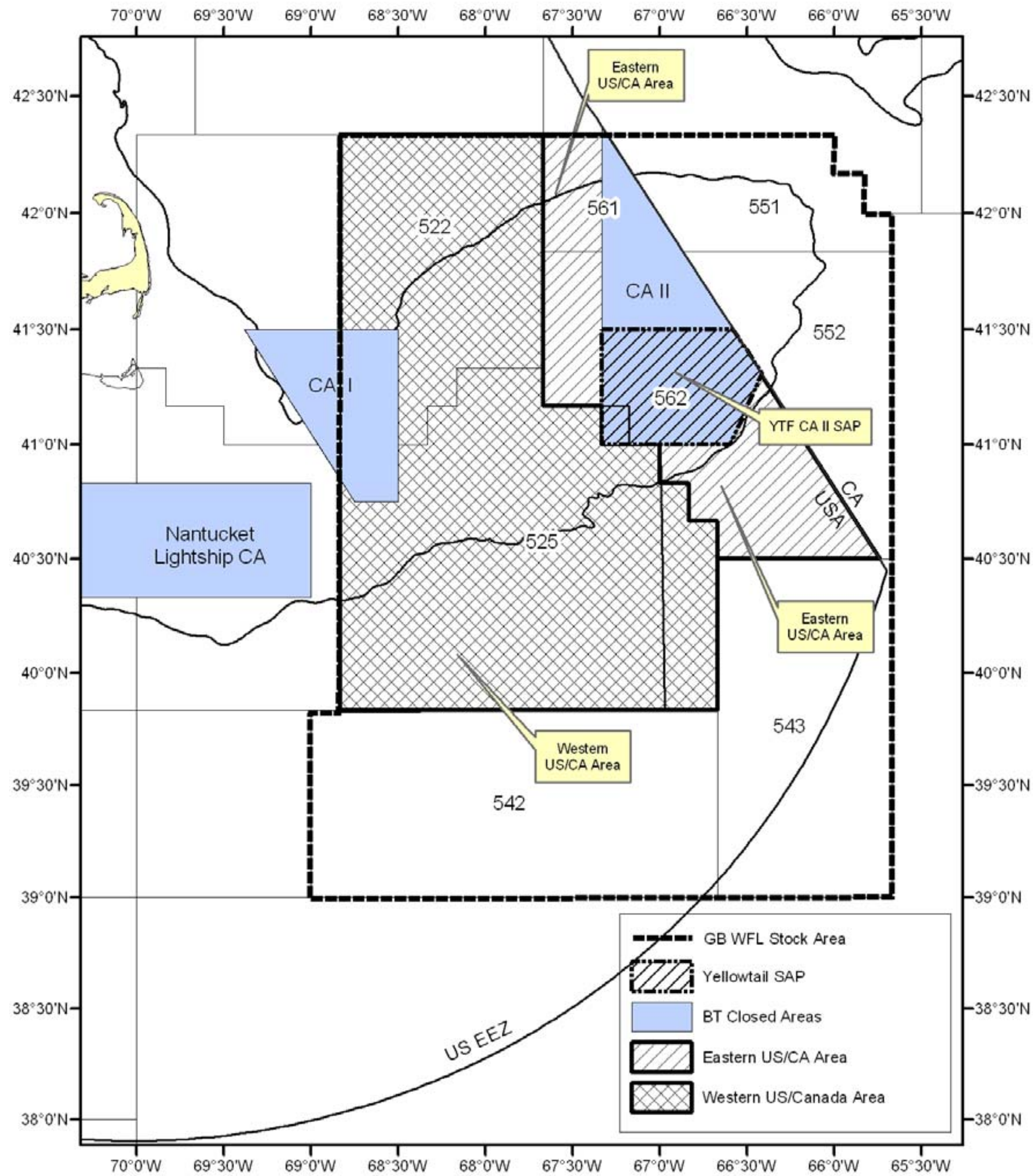


Figure B6. Management areas that impact the Georges Bank winter flounder stock (polygon denoted by a heavy dashed line). Blue polygons have been closed, since 1994, to bottom trawl vessels but have been open to scallop dredge vessels with fishery closures dependent on scallop and yellowtail flounder bycatch limits. The US/CA areas were implemented beginning in May of 2004 and involve jointly managed cod, haddock and yellowtail flounder stocks.

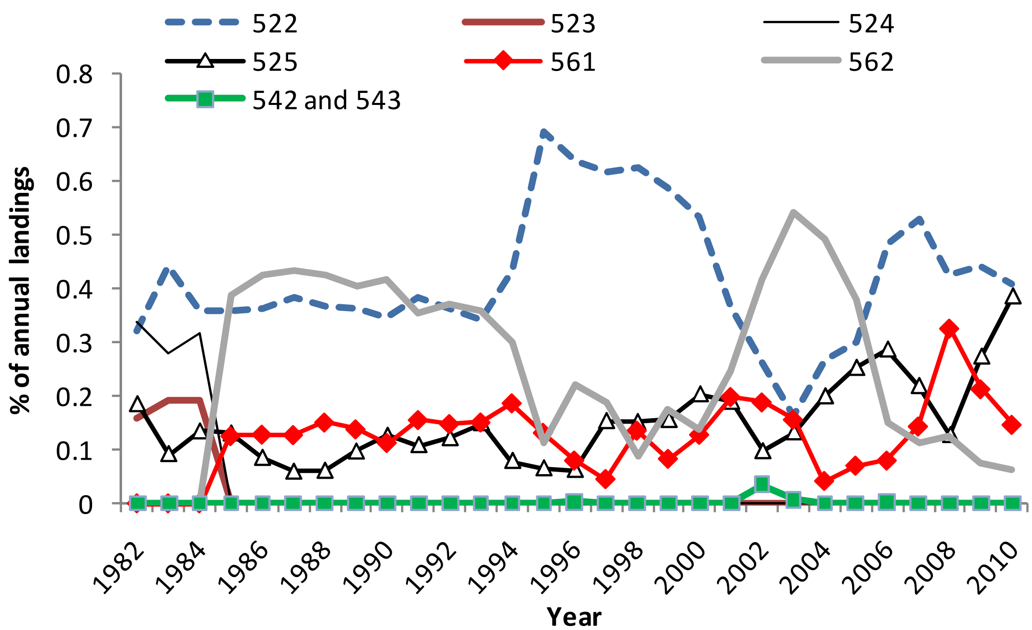


Figure B7. U.S. landings of Georges Bank winter flounder by Statistical Area.

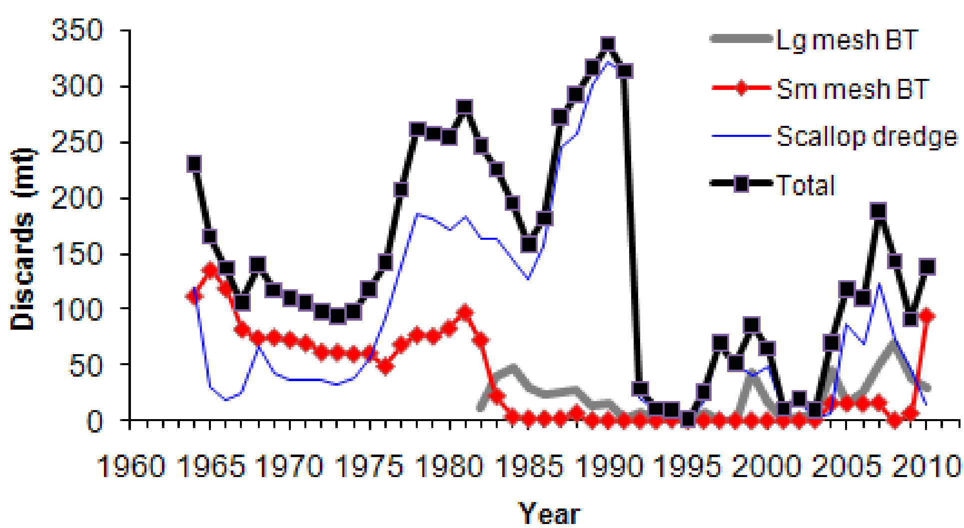


Figure B8. U.S. discards (mt) of Georges Bank winter flounder, by major gear type, during 1964-2010.

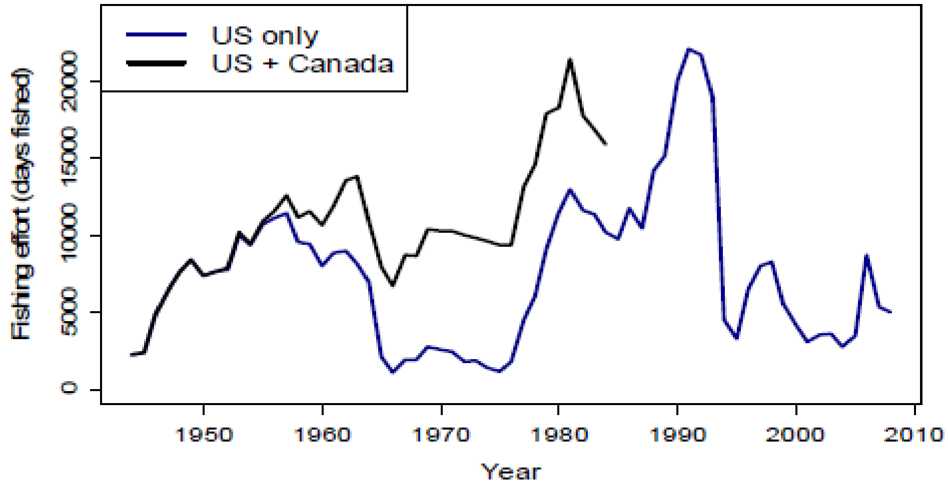


Figure B9. Fishing effort (days fished) in the US and combined US and Canadian sea scallop fisheries operating on Georges Bank, 1945-2009 (excerpted from NEFSC 2010).

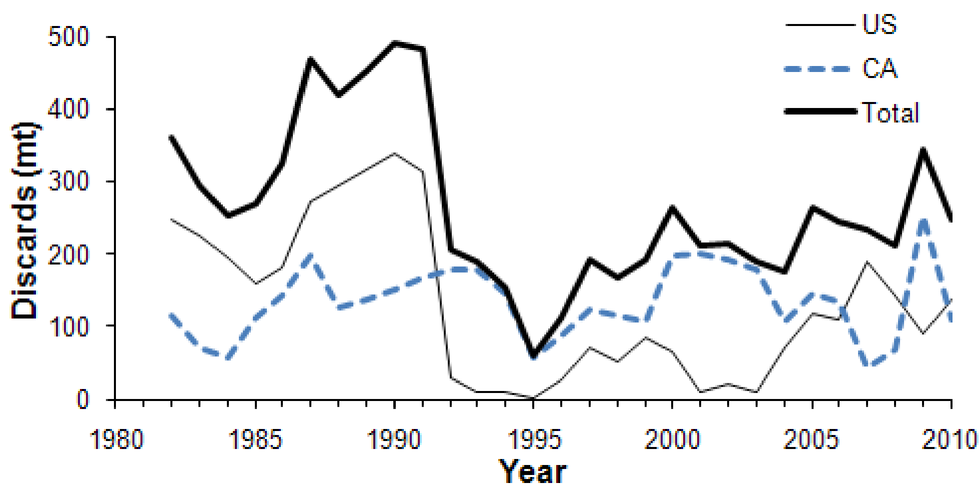


Figure B10. Estimates of total discards (mt) of Georges Bank winter flounder, by country, during 1982-2010.

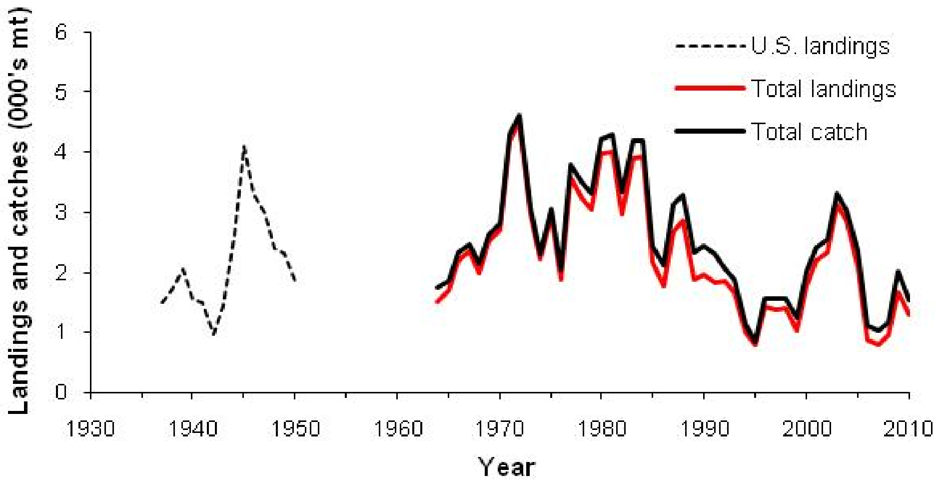


Figure B11. Historical U.S. landings of winter flounder from Georges Bank, during 1937-1950, in relation to total landings and catches during 1964-2010

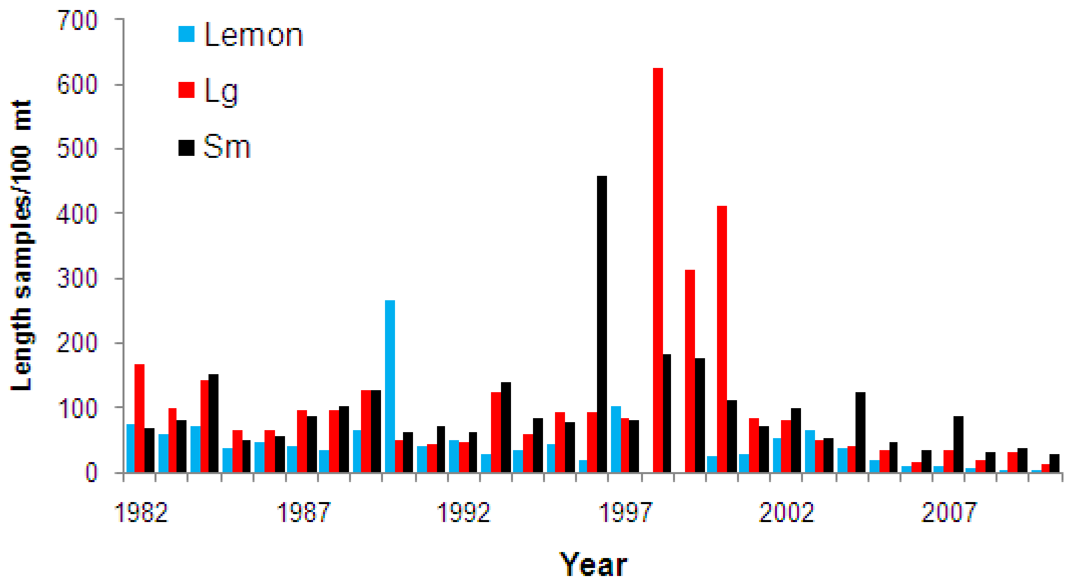


Figure B12. Length samples of Georges Bank winter flounder per 100 mt of landings, by market category group, during 1982-2010.

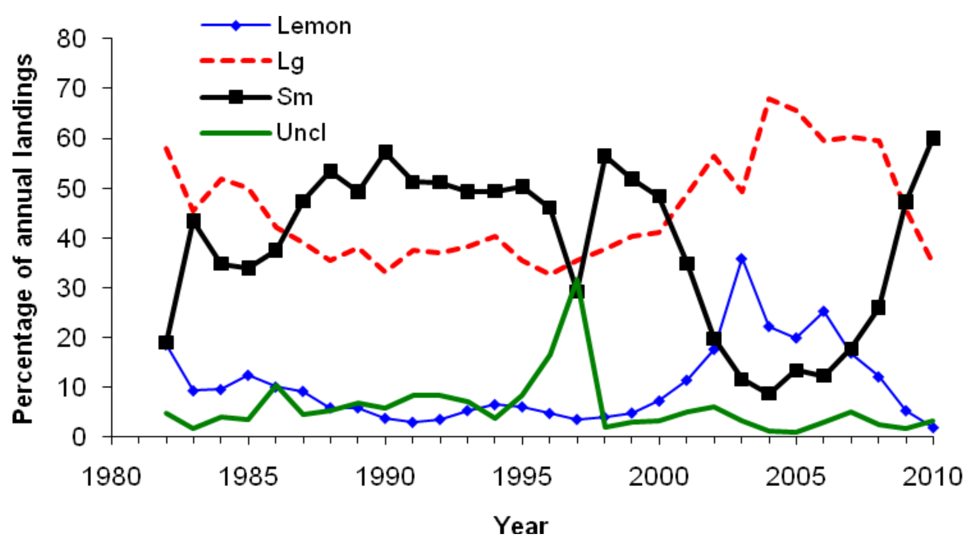


Figure B13. U.S. landings of Georges Bank winter flounder by market category group, 1982-2010.

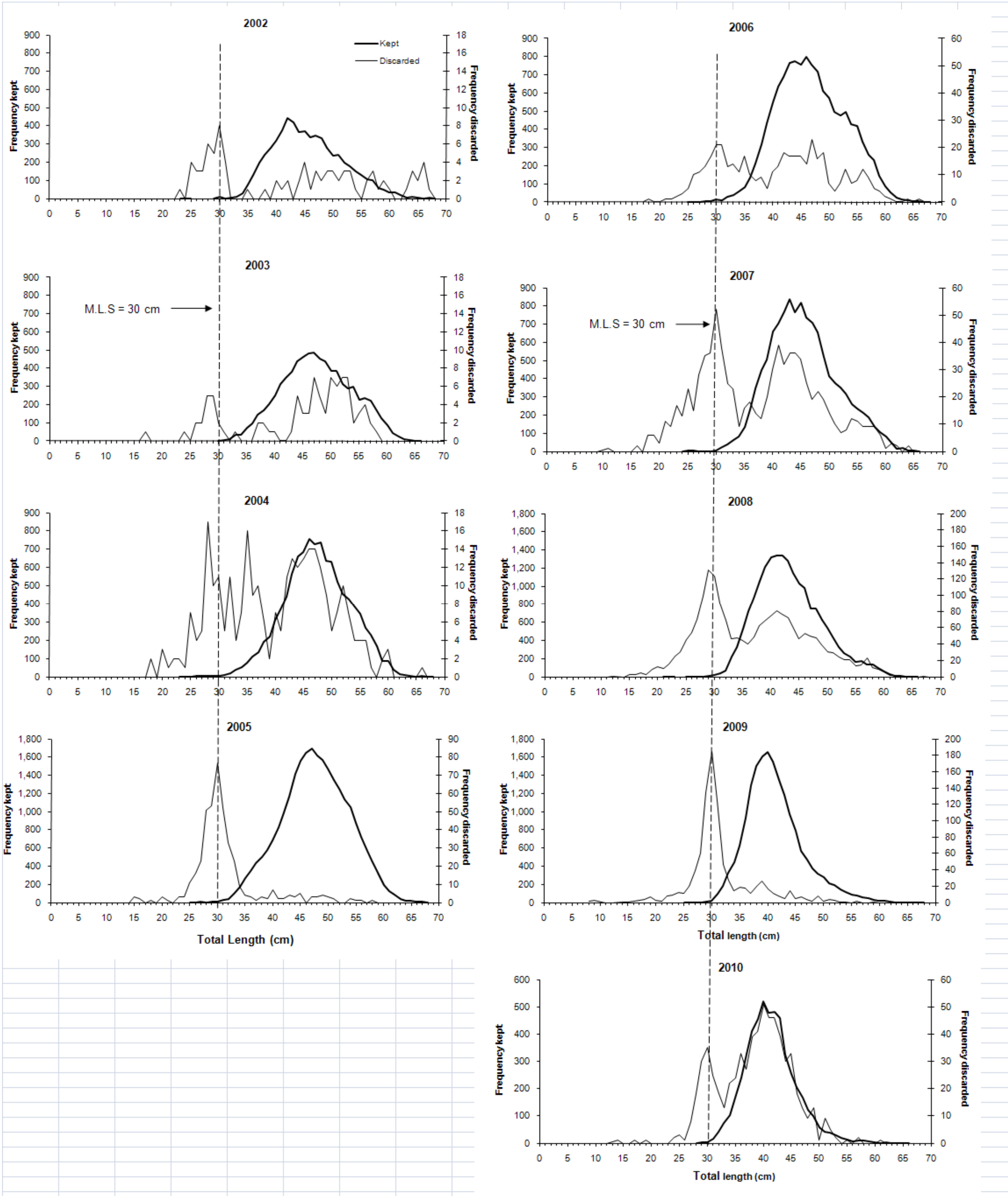


Figure B14. Length frequency distributions of Georges Bank winter flounder kept and discarded portions of bottom trawl catches sampled by fishery observers during 2002-2010.Dashed lines represent the minimum landings size limit.

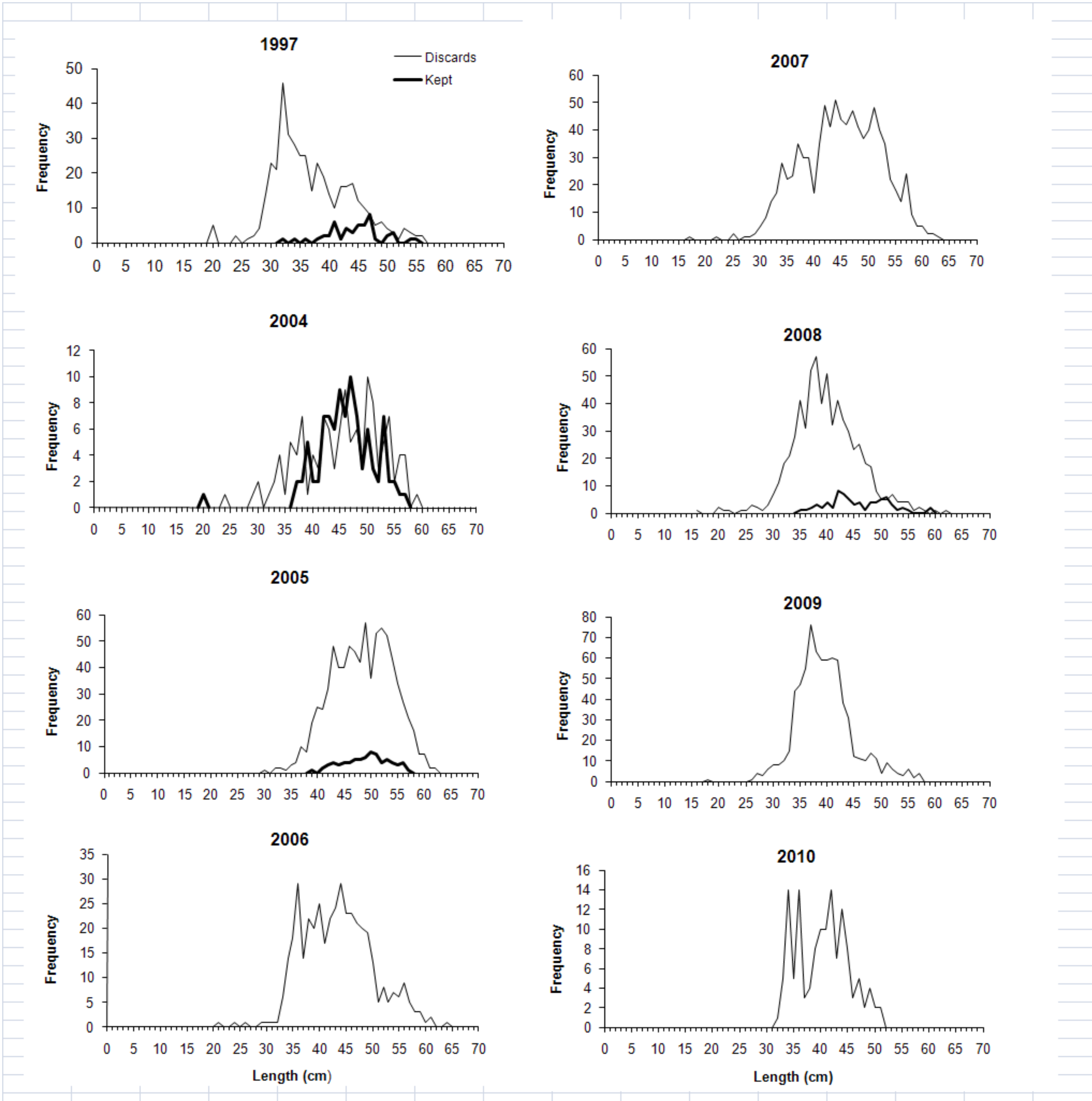


Figure B15. Length frequency distributions of Georges Bank winter flounder kept and discarded portions of scallop dredge catches sampled by fishery observers during 1997 and 2004-2010. Dashed lines represent the minimum landings size limit

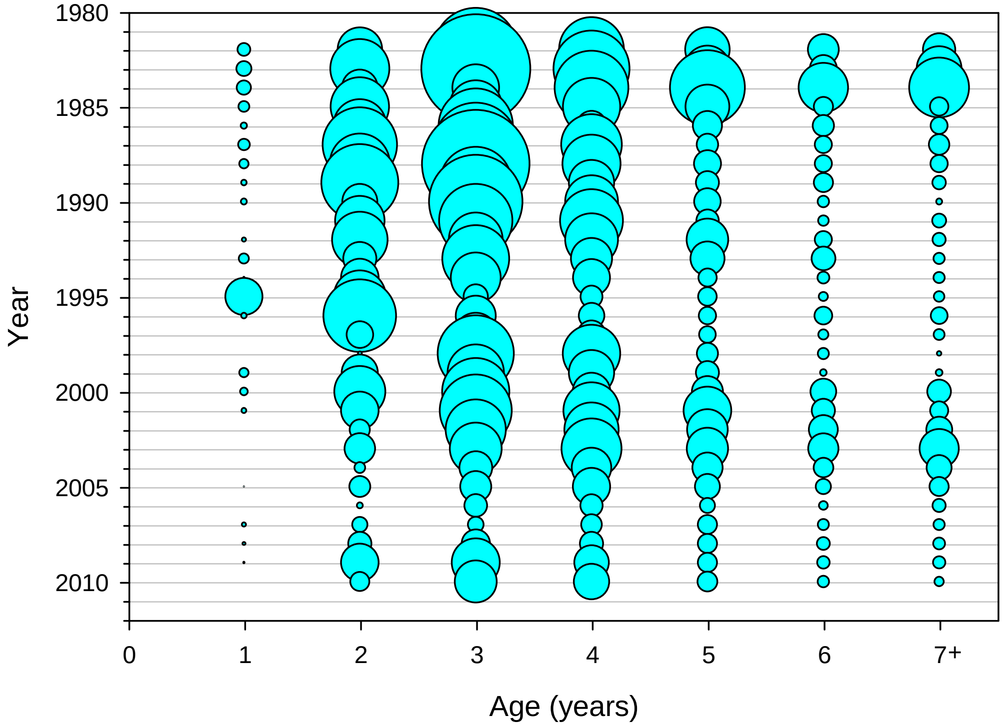


Figure B16. Georges Bank winter flounder catch-at-age during 1982-2010. Catches increase with circle size.

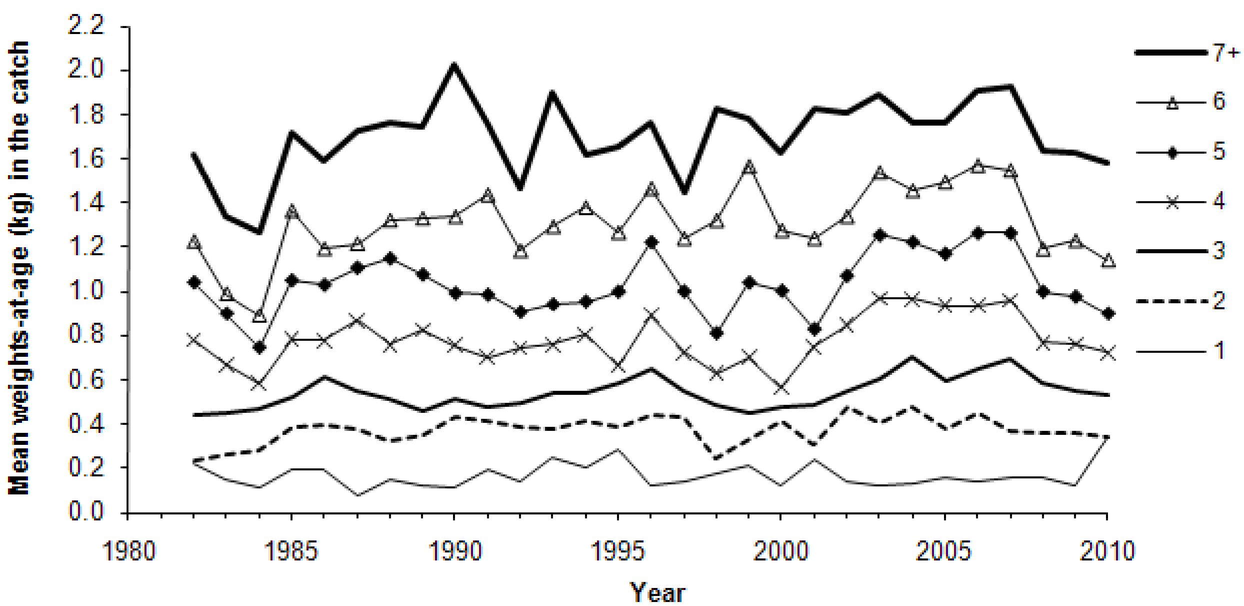


Figure B17. Trends in mean weights-at-age (kg) in the catches of GB winter flounder, 1982-2010.

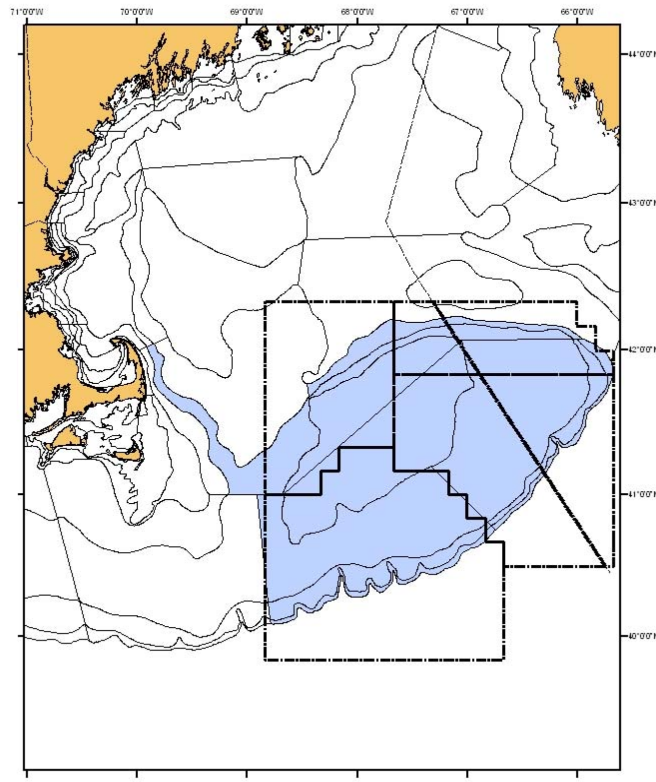


Figure B18. NEFSC survey strata (13-23) included in the assessment of Georges Bank winter flounder in relation to fishery Statistical Areas for the stock.

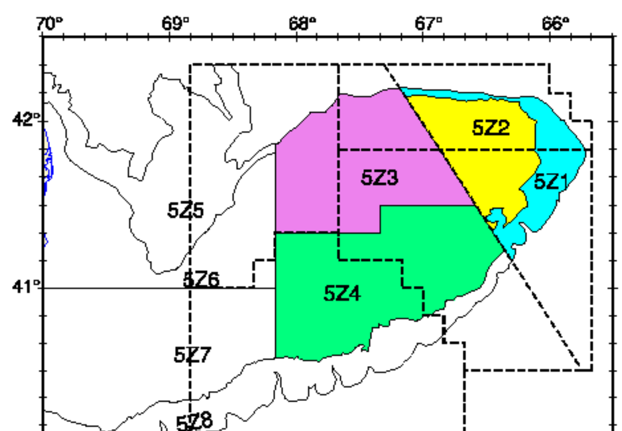


Figure B19. Strata (5Z1-5Z4) from the Canadian spring survey included in the assessment of Georges Bank winter flounder in relation to fishery Statistical Areas for the stock.

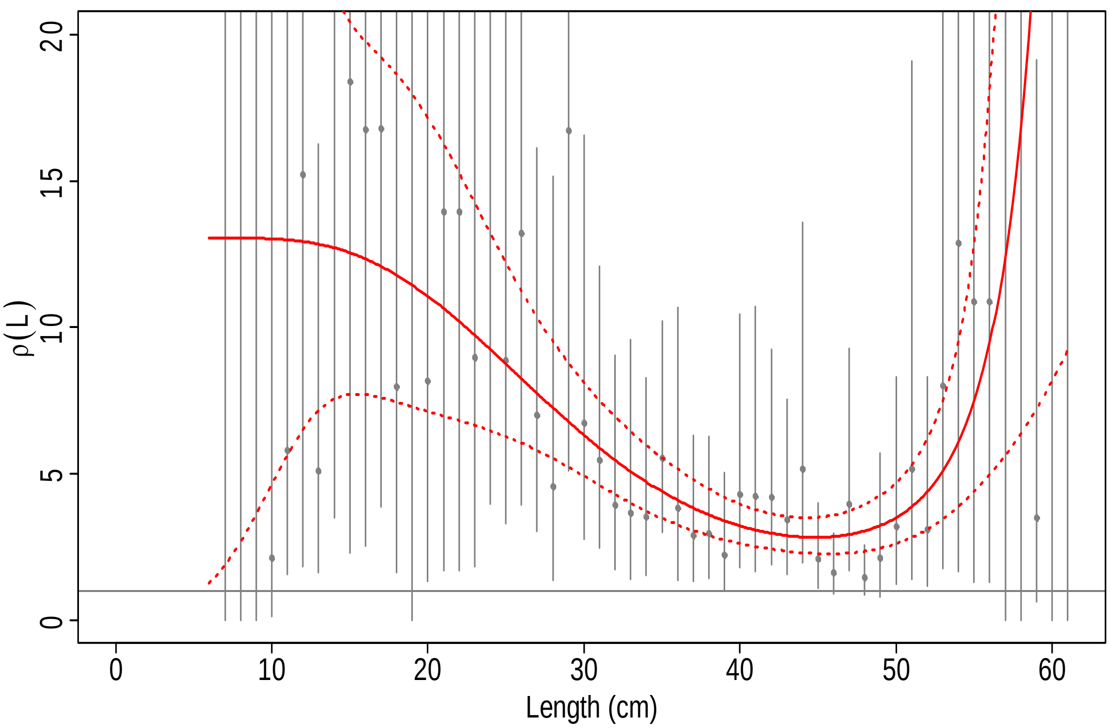
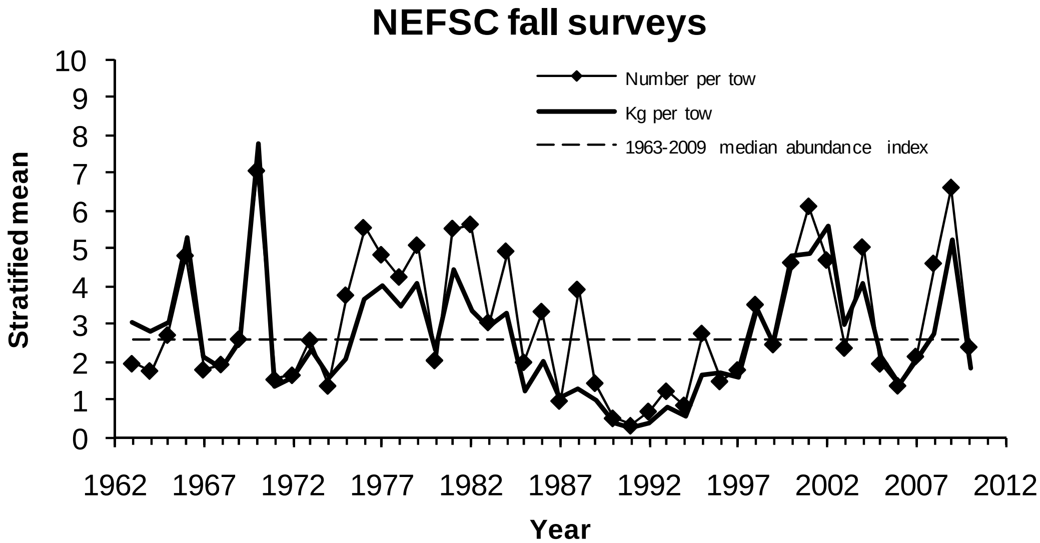


Figure B20. Relative catch efficiency of Georges Bank winter flounder from a beta-binomial model where relative catch efficiency was modeled as an orthogonal polynomial smoother of length (solid red line) and from separate models fit to catch data in each length class (gray points). The dashed red lines and vertical gray lines represent approximate 95% confidence intervals. The horizontal gray line represents equal efficiency of the SRVs *Henry B. Bigelow* and *Albatross IV*.



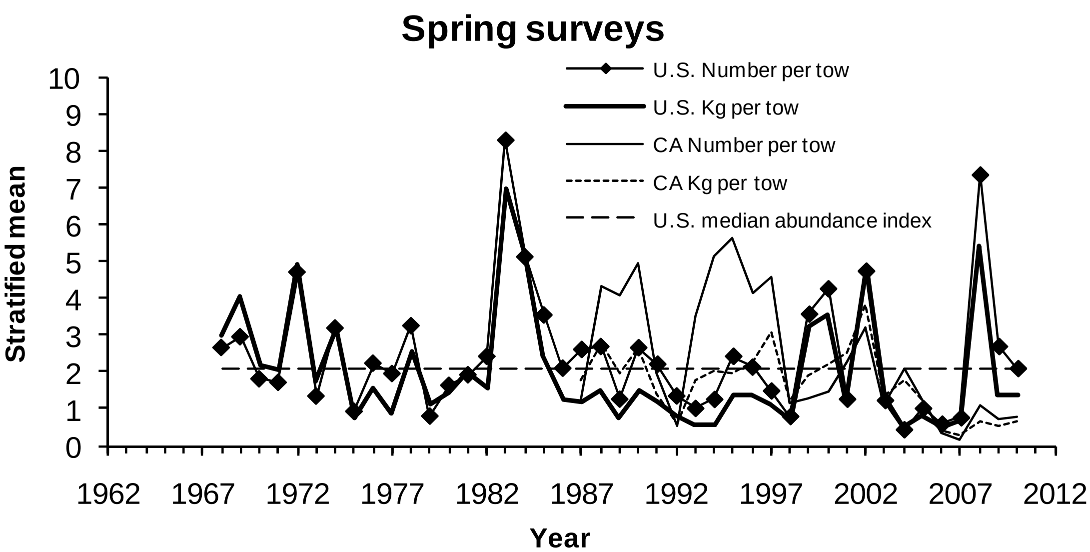


Figure B21. Relative biomass (stratified mean kg per tow) and abundance (stratified mean numbers per tow) indices for Georges Bank winter flounder caught during (top) NEFSC fall (1963-2010) bottom trawl surveys and (bottom) NEFSC spring (1968-2010) and Canadian spring (1987-2010 strata 5Z1-5Z4) bottom trawl surveys. NEFSC survey indices include strata 13-23 and were standardized for gear changes (weight = 1.86 and numbers = 2.02) and trawl door changes (weight = 1.39 and numbers = 1.46) prior to 1985. NEFSC indices for the SRV *H.B. Bigelow*, from 2009 onward, were converted to SRV *Albatross* equivalents using length-based conversion factors.

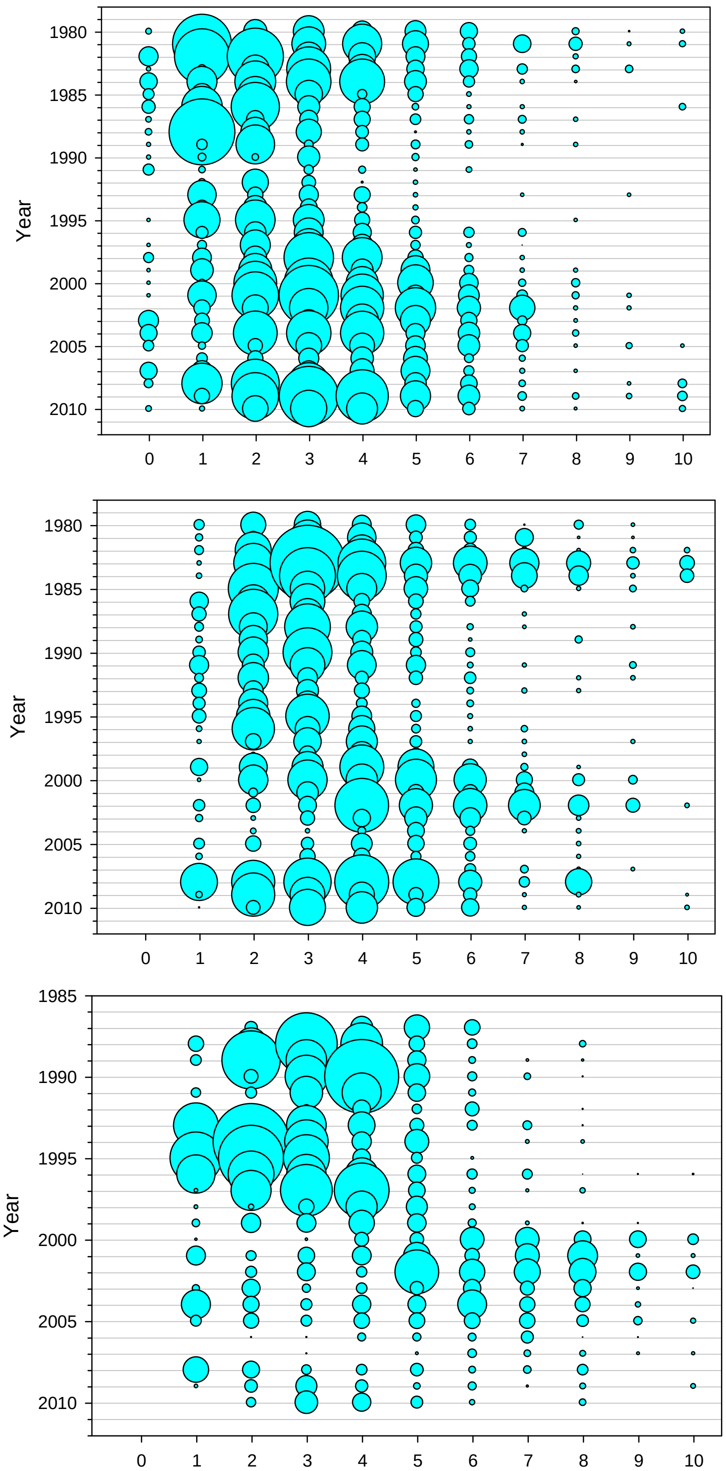


Figure B22. Stratified mean number per tow-at-age indices for (top) NEFSC fall bottom trawl surveys (1963-2010), (middle) NEFSC spring surveys (1968-2010) and (bottom) CA spring surveys (1987-2010). Relative abundance increases with circle size.

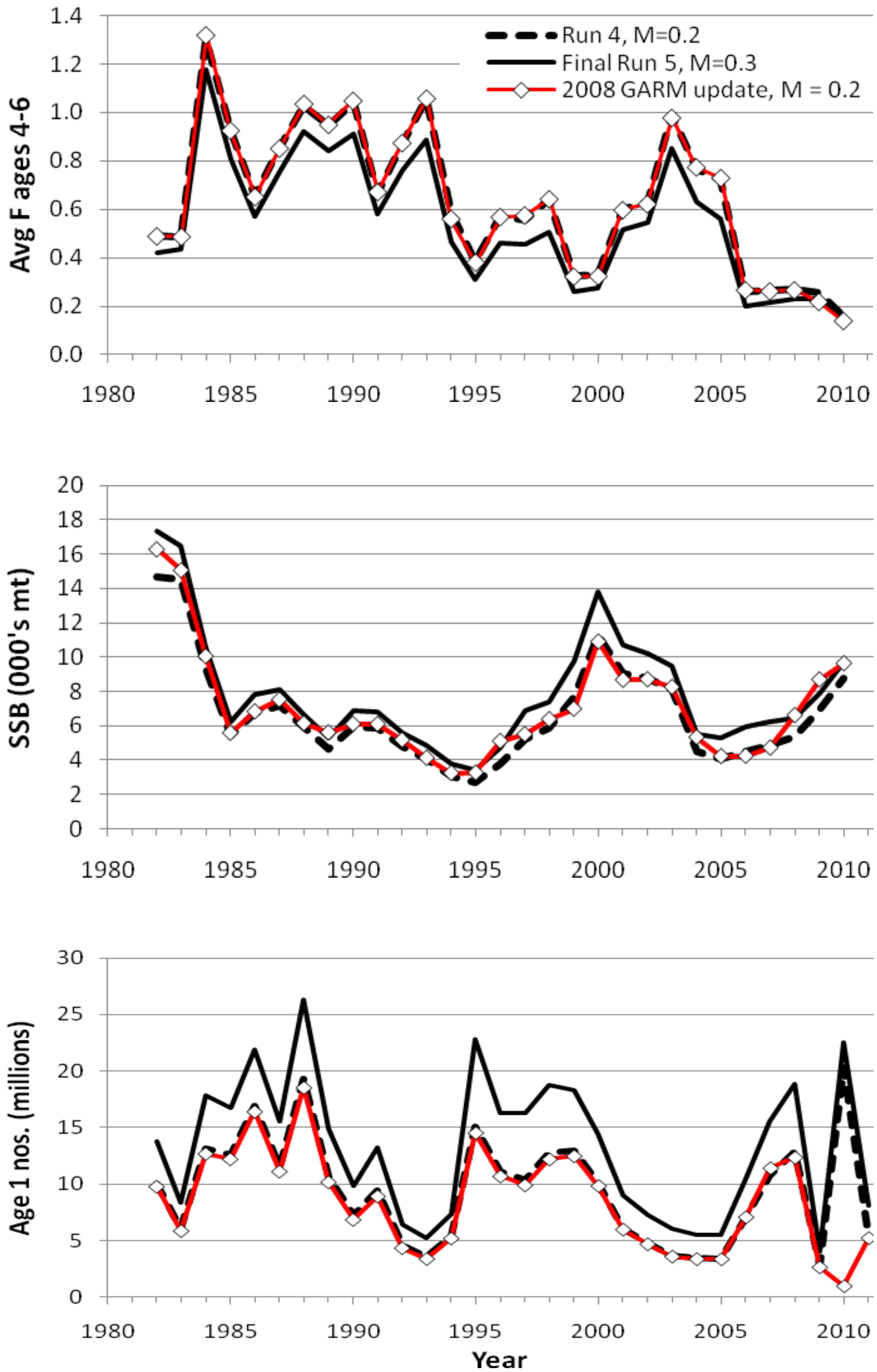


Figure B23. Comparison of trends in average fishing mortality rate (on ages 4-6), spawning stock biomass (SSB, 000's mt), and age 1 recruitment (nos. in millions) for the final VPA model run and Run 4 (same input data as final model run, but M = 0.2), from SARC 52, versus the updated 2008 GARM run.

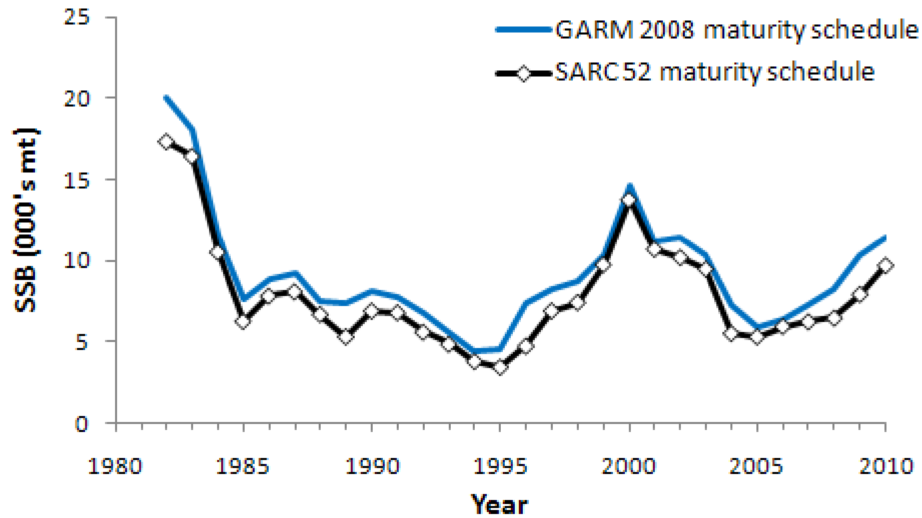


Figure B24. The effect of a change in the maturity-at-age schedule on Georges Bank winter flounder SSB estimates (000's mt) for 1982-2010, from the SARC 52 final VPA run. The SARC 52 final VPA run incorporated a three-year moving window of maturity-at-age for 1981-2010 (corrected for improperly assigned maturity stages based on female gonad histology data) and the VPA run from the 2008 GARM incorporated a constant, average maturity-at-age schedule for 1982-2007. Both runs incorporated an instantaneous natural mortality rate of 0.3.

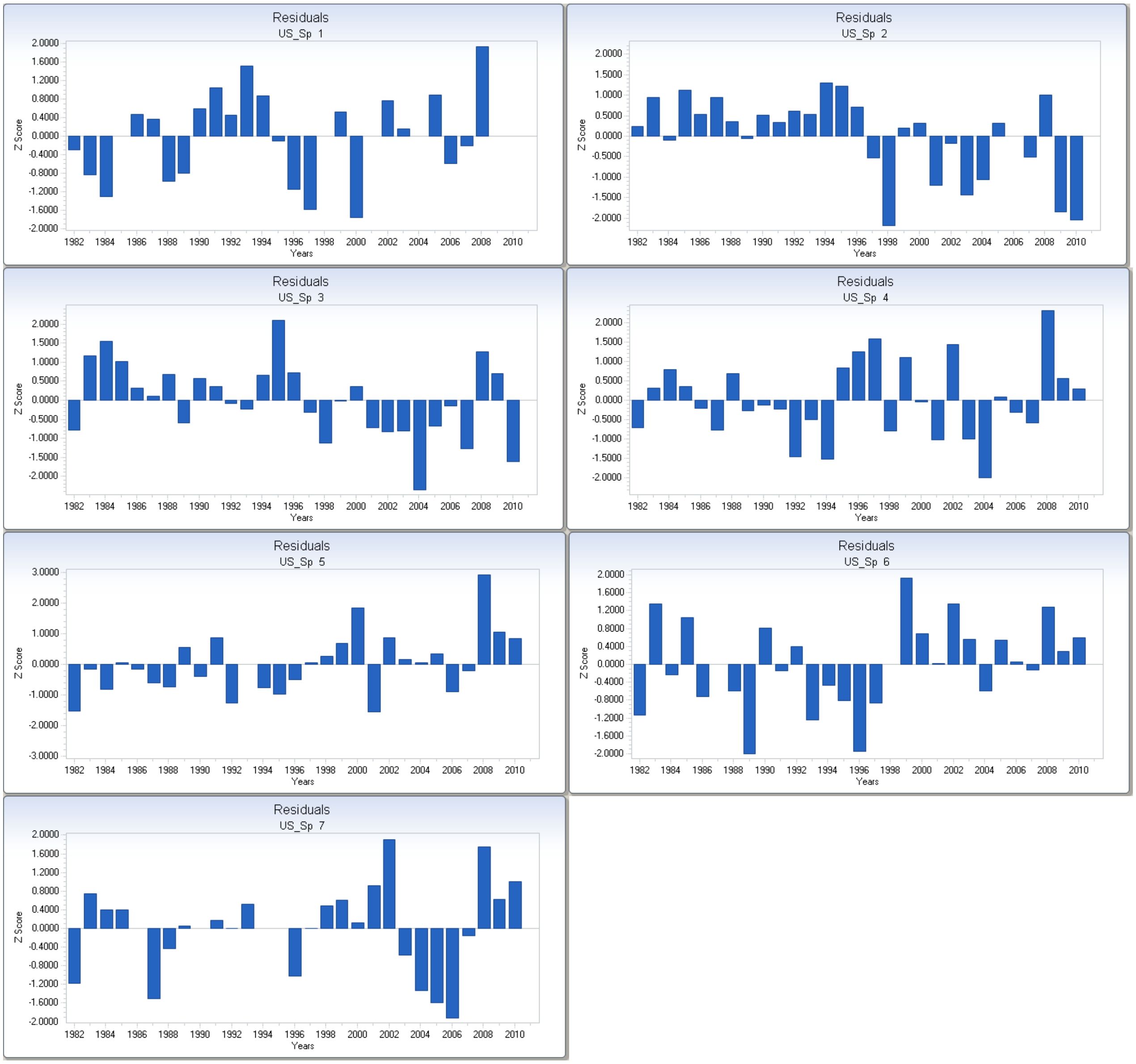


Figure B25. Weighted residuals, plotted as Z scores, from the NEFSC spring bottom trawl survey indices (ages 1-7+, 1982-2010) used to calibrate the VPA model for Georges Bank winter flounder.

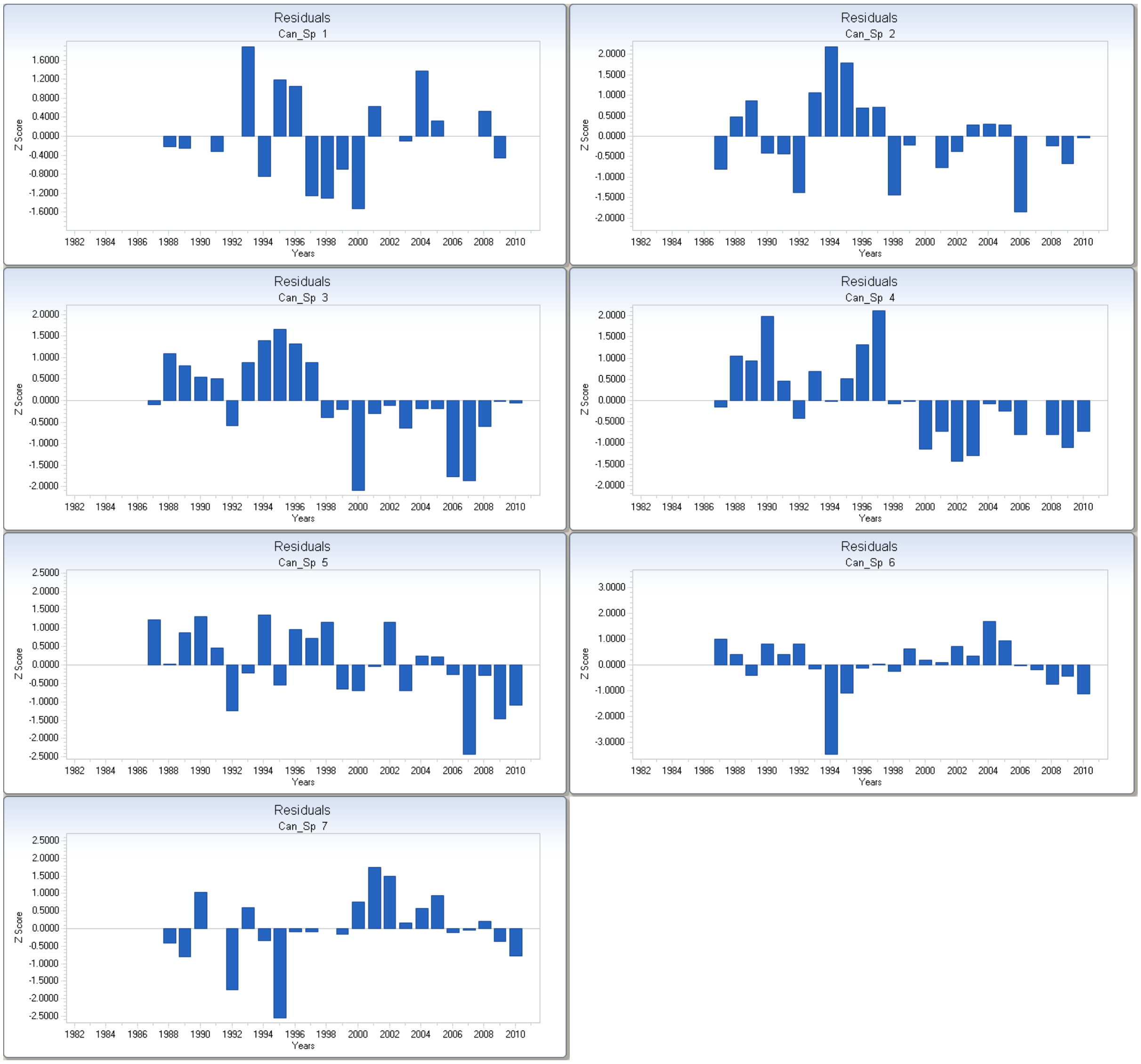


Figure B26. Weighted residuals, plotted as Z scores, from the Canadian spring bottom trawl survey indices (ages 1-7+, 1982-2010) used to calibrate the VPA model for Georges Bank winter flounder.

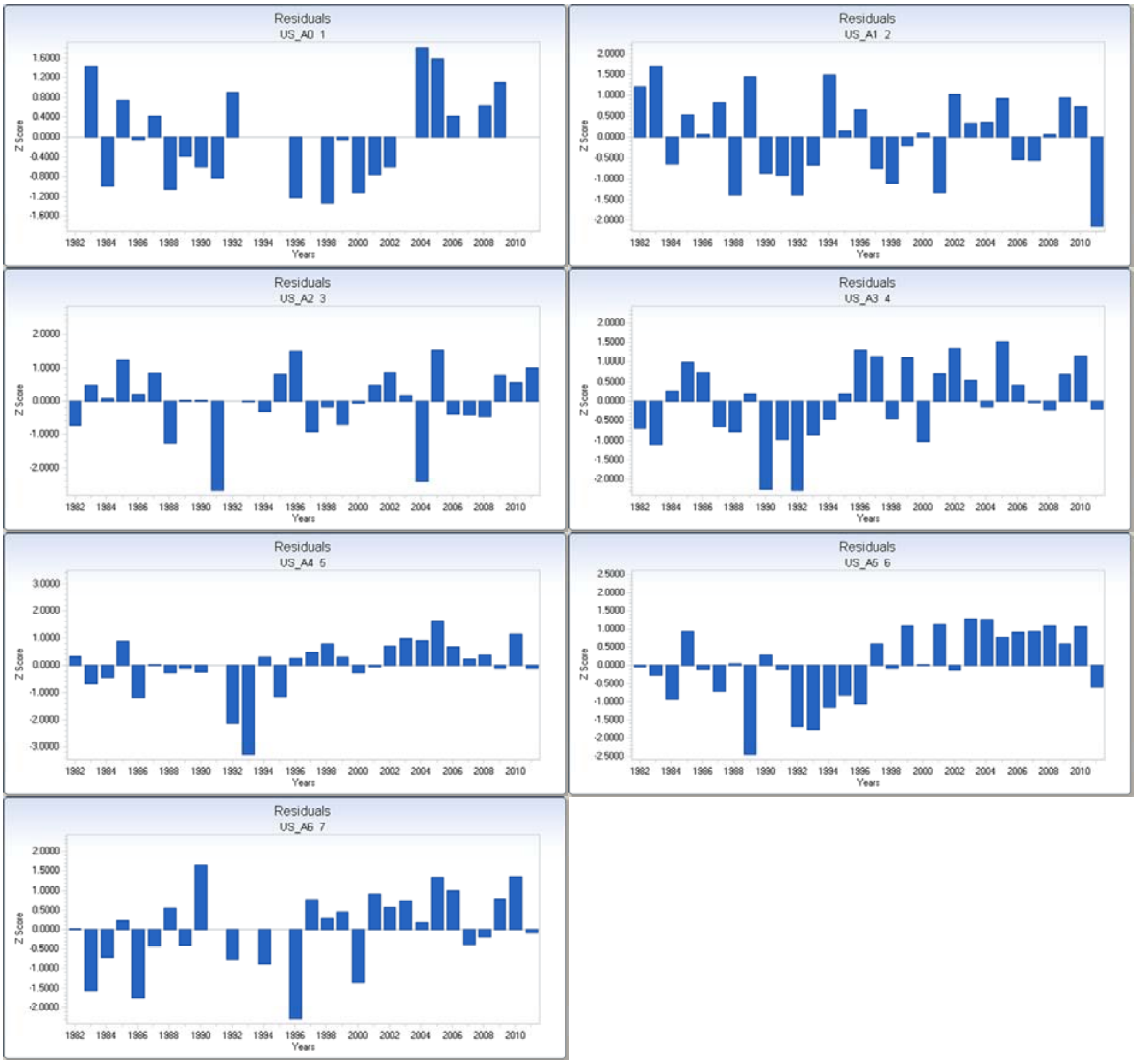


Figure B27. Weighted residuals, plotted as Z scores, from the US fall bottom trawl survey indices (ages 0-6 forwarded one year and age, 1981-2010) used to calibrate the VPA model for Georges Bank winter flounder.

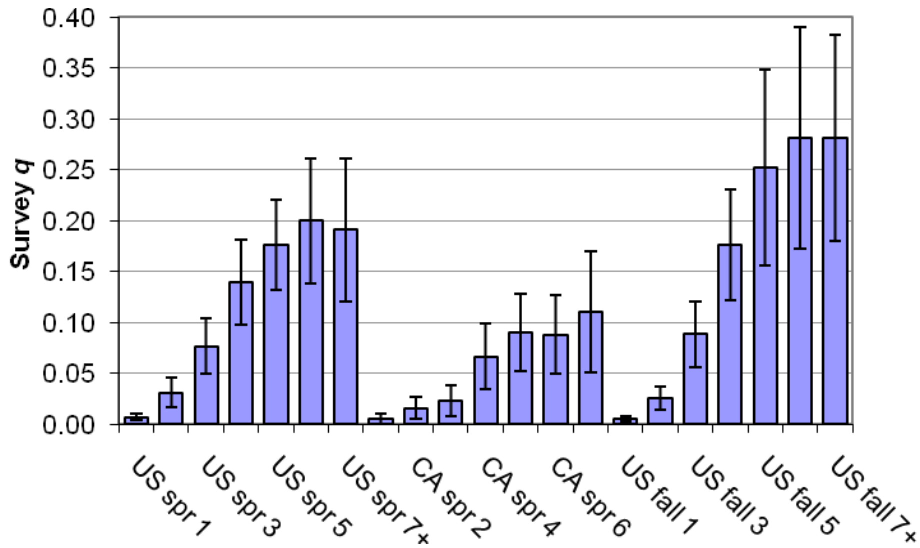


Figure B28. Estimates of survey catchability coefficients (+/- 2 SE) for the final VPA model run, by age, for Georges Bank winter flounder caught during the US spring (1982-2010, ages 1-7+), Canadian spring (1987-2010, ages 1-7+), and US fall (1981-2010, ages 0-6 lagged forward one year and age) bottom trawl surveys.

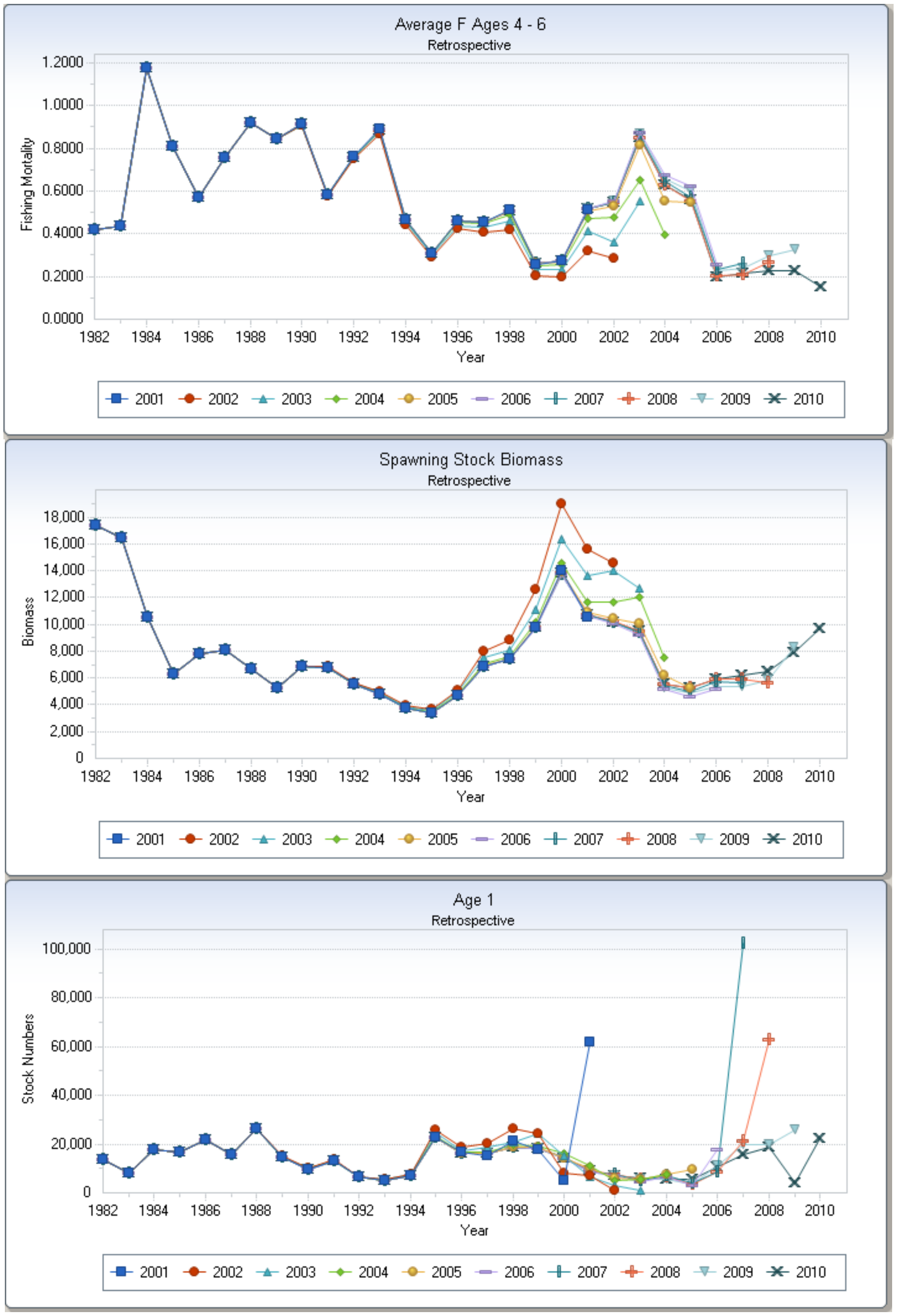


Figure B29. Retrospective trends in terminal years 2001-2009 for average fishing mortality rates (top panel), spawning stock biomass (mt, middle panel), and age 1 recruitment (numbers in thousands, bottom panel) from the Georges Bank winter flounder VPA model (1982-2010).

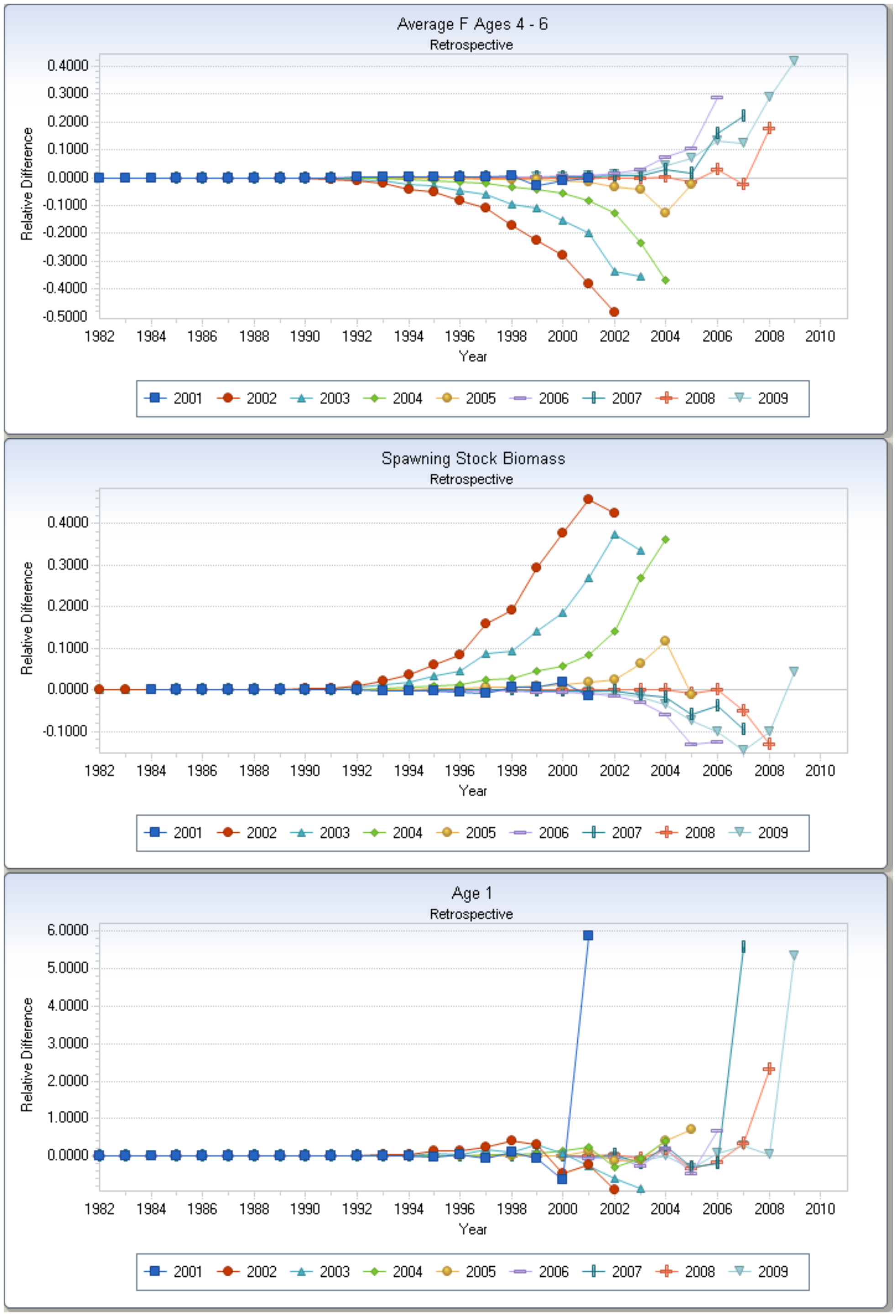


Figure B30. Retrospective trends in relative differences between average F (ages 4-6, top panel), spawning stock biomass (mt, middle panel), and age 1 recruitment estimates (bottom panel), between terminal years 2001-2009 and 2010, from the Georges Bank winter flounder VPA model (1982-2010).

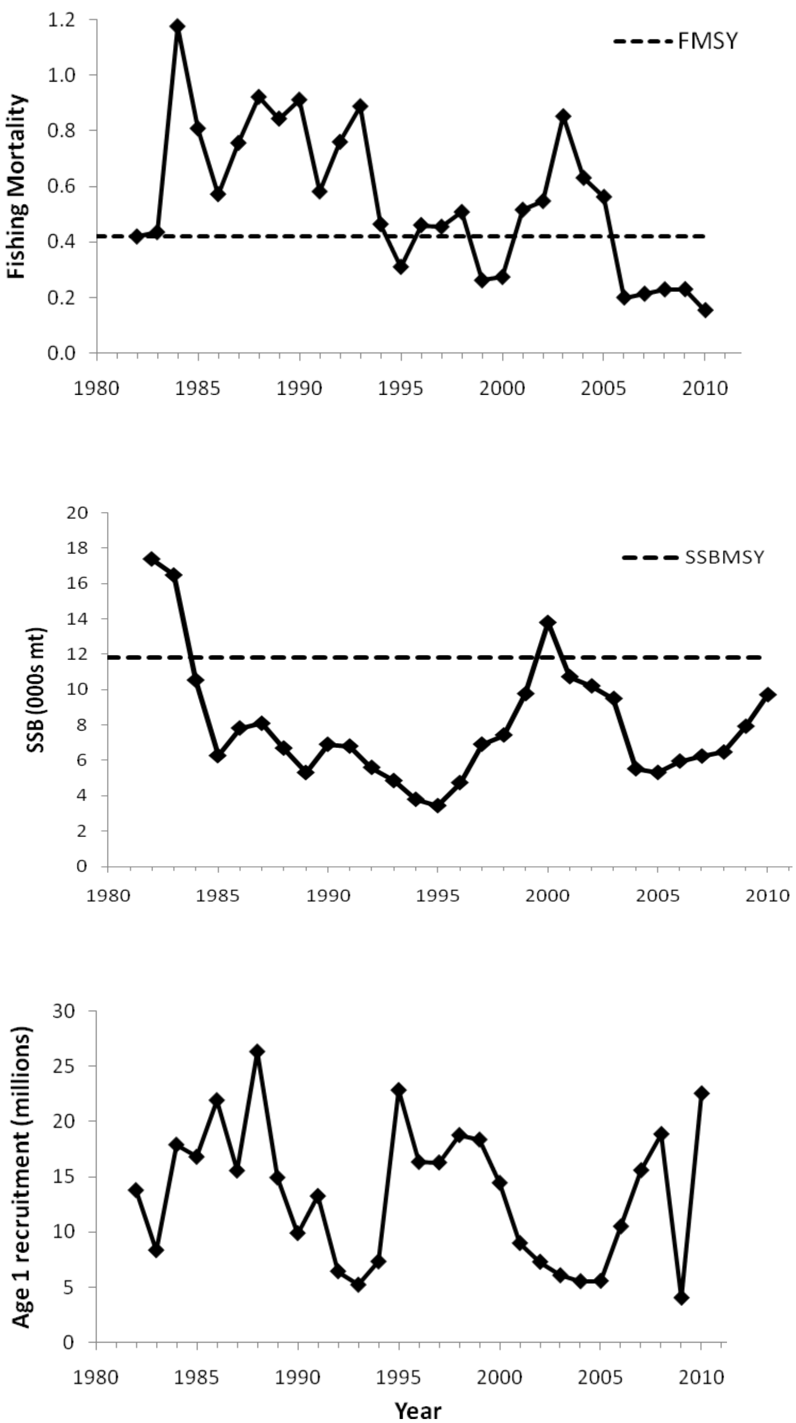


Figure B31. Final VPA model estimates of average fishing mortality rate (ages 4-6, top panel), spawning stock biomass (000's mt, middle panel), during 1982-2010, and age 1 recruitment (numbers in thousands), during 1982-2011 (bottom panel), for the Georges Bank winter flounder stock. The 2011 recruitment estimate is solely based on survey data (2003-2009 geometric mean of recruitment).

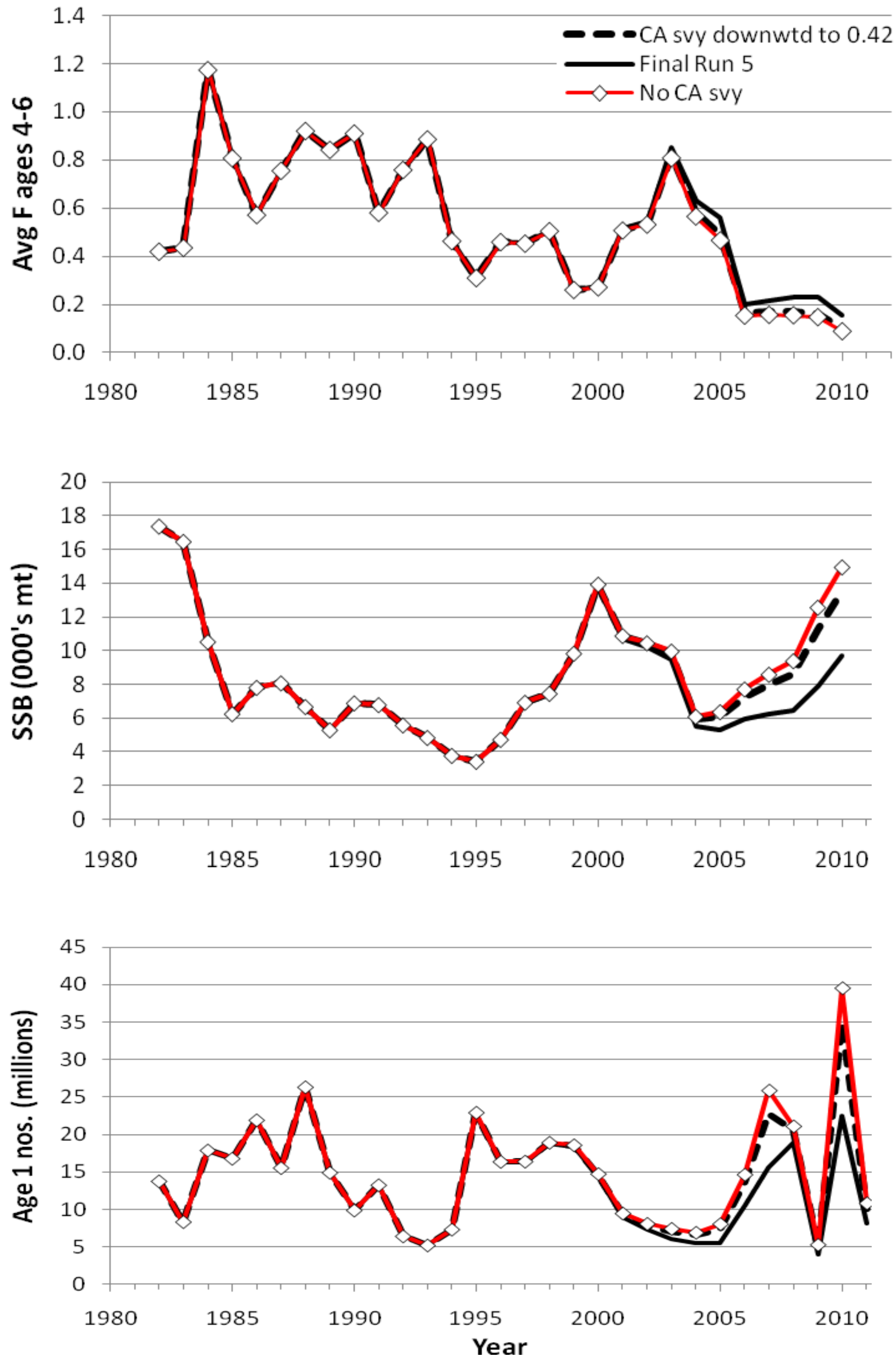


Figure B32. Comparison of trends in average fishing mortality rate (on ages 4-6), spawning stock biomass (SSB, 000's mt), and age 1 recruitment (nos. in millions) for the final VPA model Run 5 versus sensitivity Runs 2 and 3, which include the same input data except with omission of the CA surveys and with the CA survey residuals downweighted by 0.42, respectively.

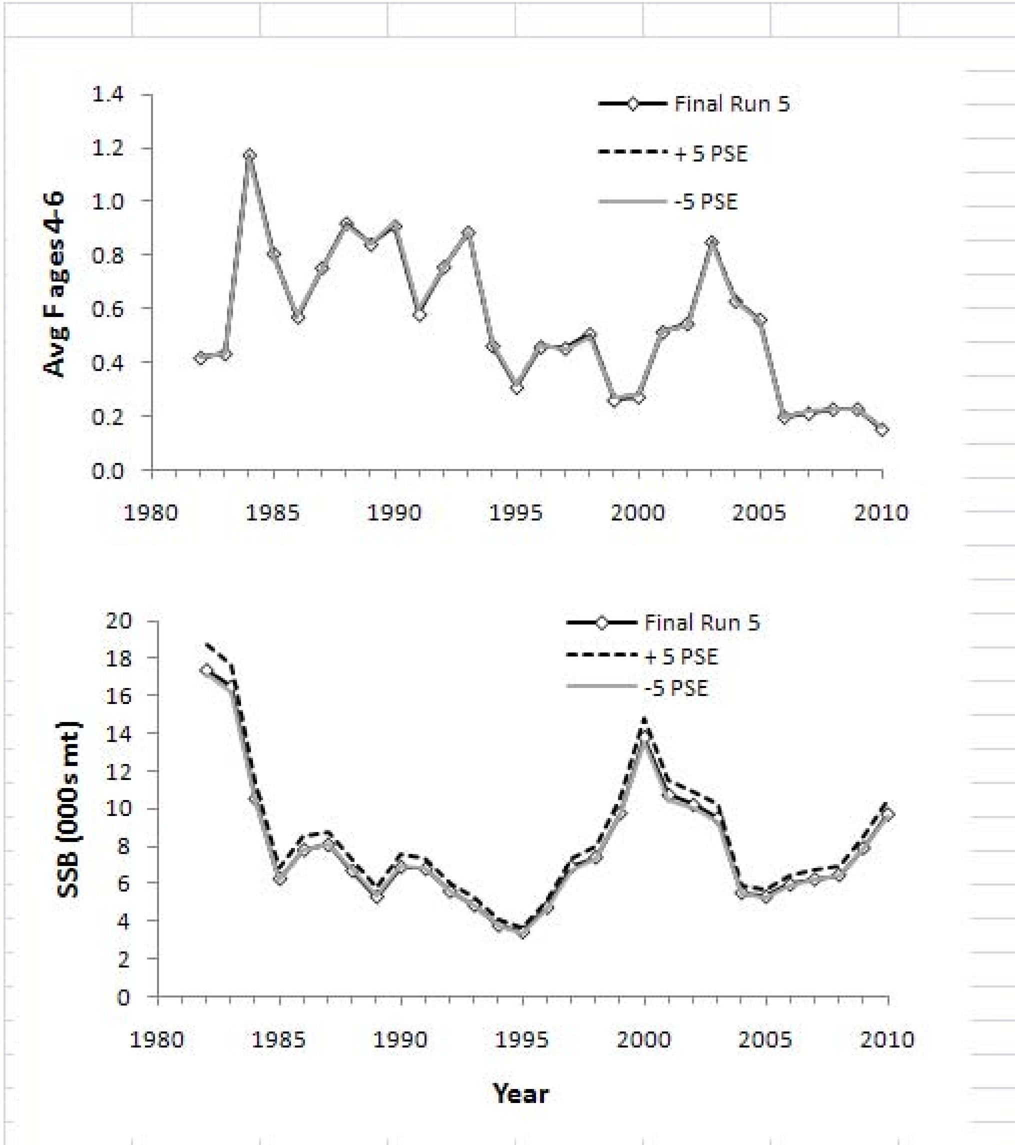


Figure B33. Trends in Georges Bank winter flounder fishing mortality rates (ages 4-6) and spawning stock biomass (SSB, 000's mt) estimates from the final VPA model (Run 5) and for model runs with +/- 5 proportional standard error (% PSE) for total catch.

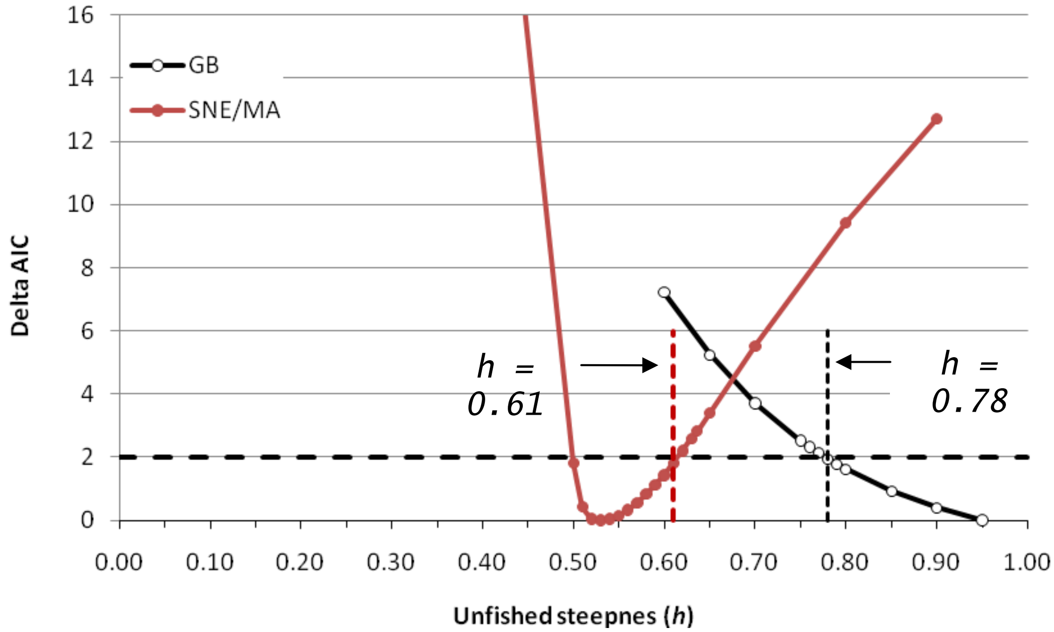


Figure B34. Log-likelihood profiles on unfished steepness parameters from Beverton-Holt stock-recruitment models for the SNE/MA and Georges Bank winter flounder stocks. The vertical dashed lines indicate the fixed steepness values which were used to estimate FMSY reference points. Delta AIC was computed as the difference between the AIC for each steepness value in the profile and the lowest AIC value.

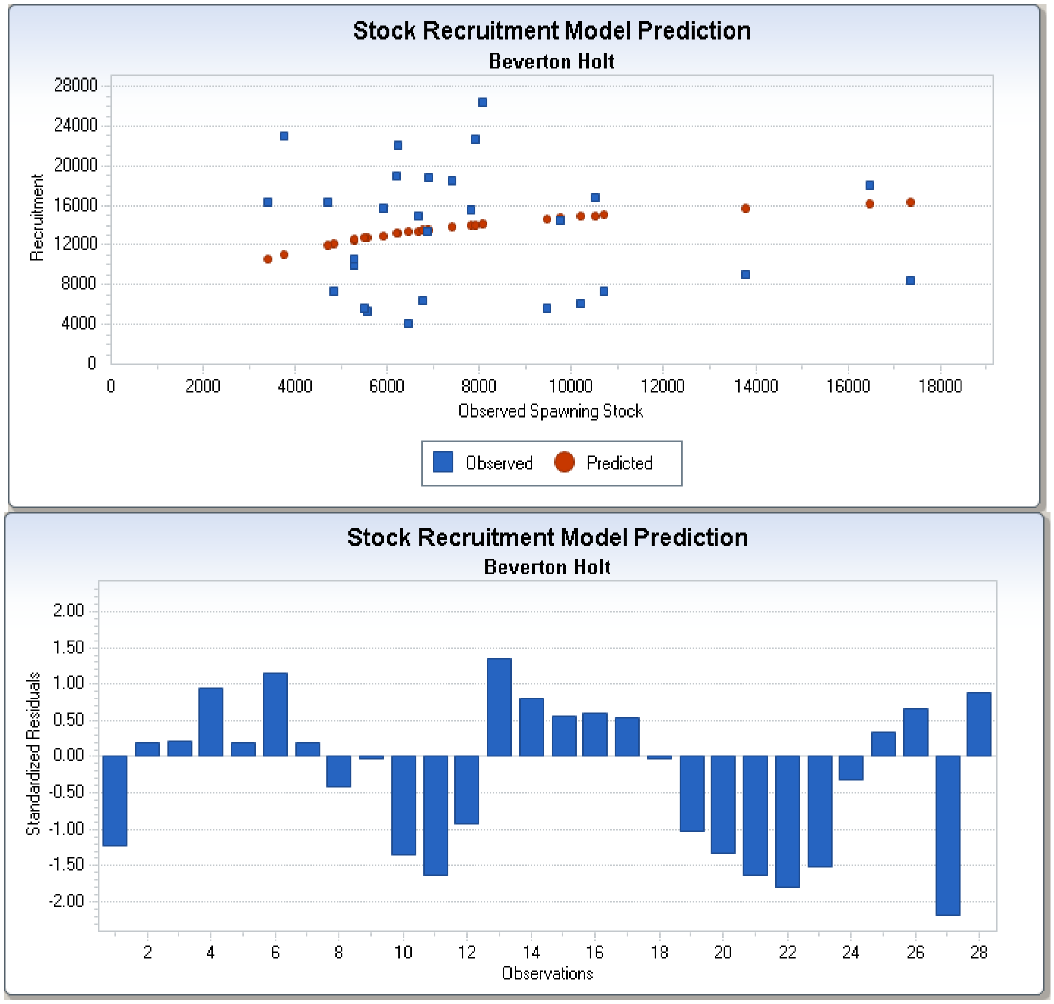


Figure B35. Results from a Beverton-Holt stock recruitment model fit to Georges Bank winter flounder estimates of recruitment (age 1 numbers in thousands, 1982-2009 year classes) and spawning stock biomass (mt) from the final VPA model (top panel). The model was fit assuming a fixed value of 0.78 for unfished steepness (*h*). The bottom panel shows the standardized residuals from the model.

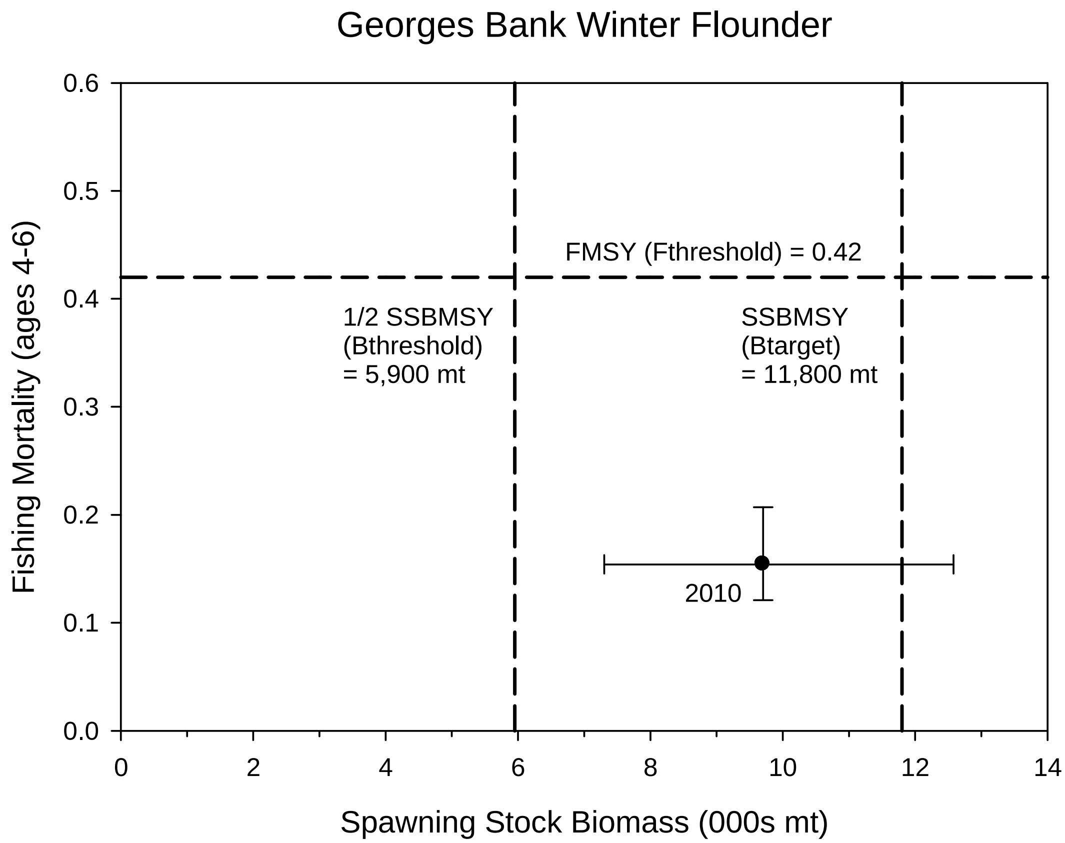
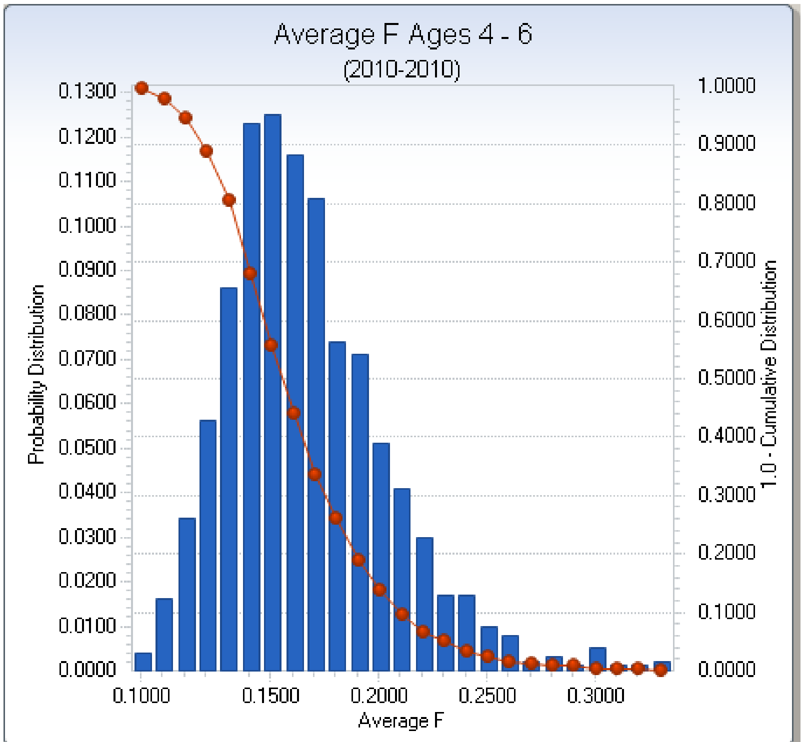


Figure B36. Stock status for Georges Bank winter flounder, during 2010, based on FMSY and SSBMSY reference points.



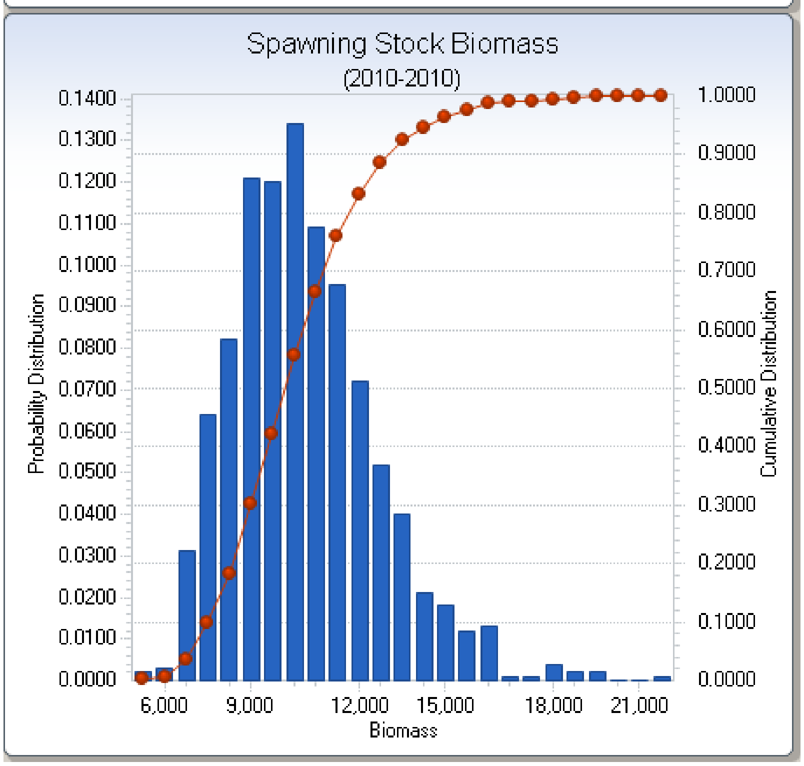


Figure B37. Precision (80% CI) of the 2010 estimates of average fishing mortality rate on ages 4-6 and spawning stock biomass (mt) from the final VPA model for Georges Bank winter flounder.

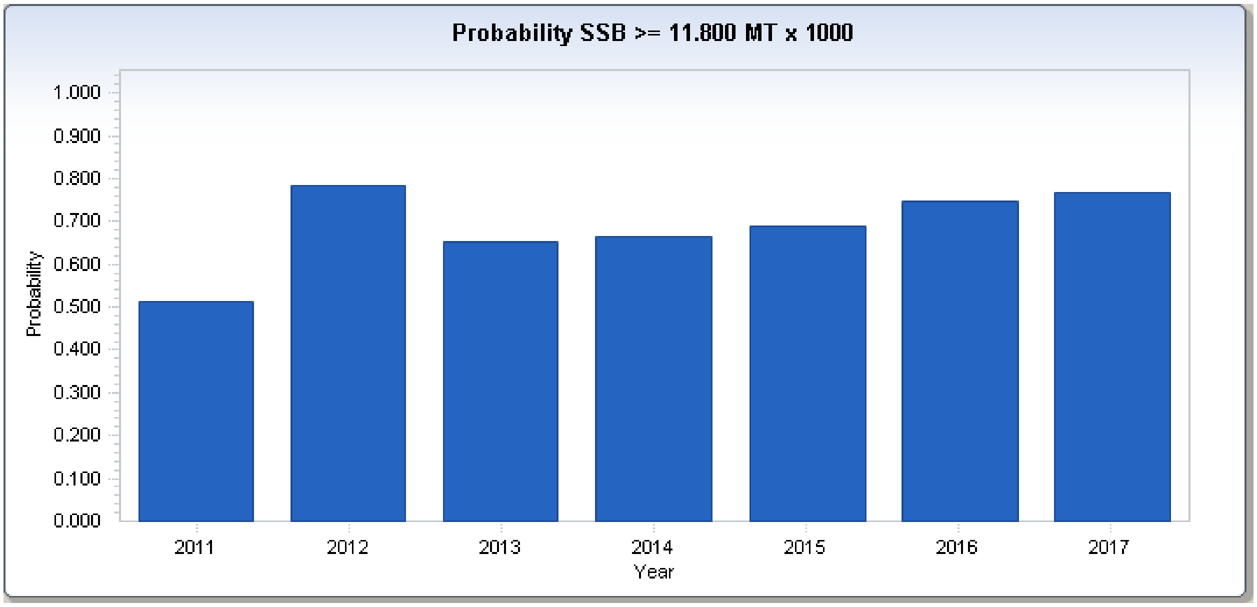


Figure B38. Probability of the Georges Bank winter flounder stock being rebuilt to SSBMSY (= 11,800 mt by 2017 based on a 2011 Annual Catch Limit of 2,118 mt and fishing at 75% of FMSY (= 0.315). The regulations require a probability of being rebuilt of at least 75%.

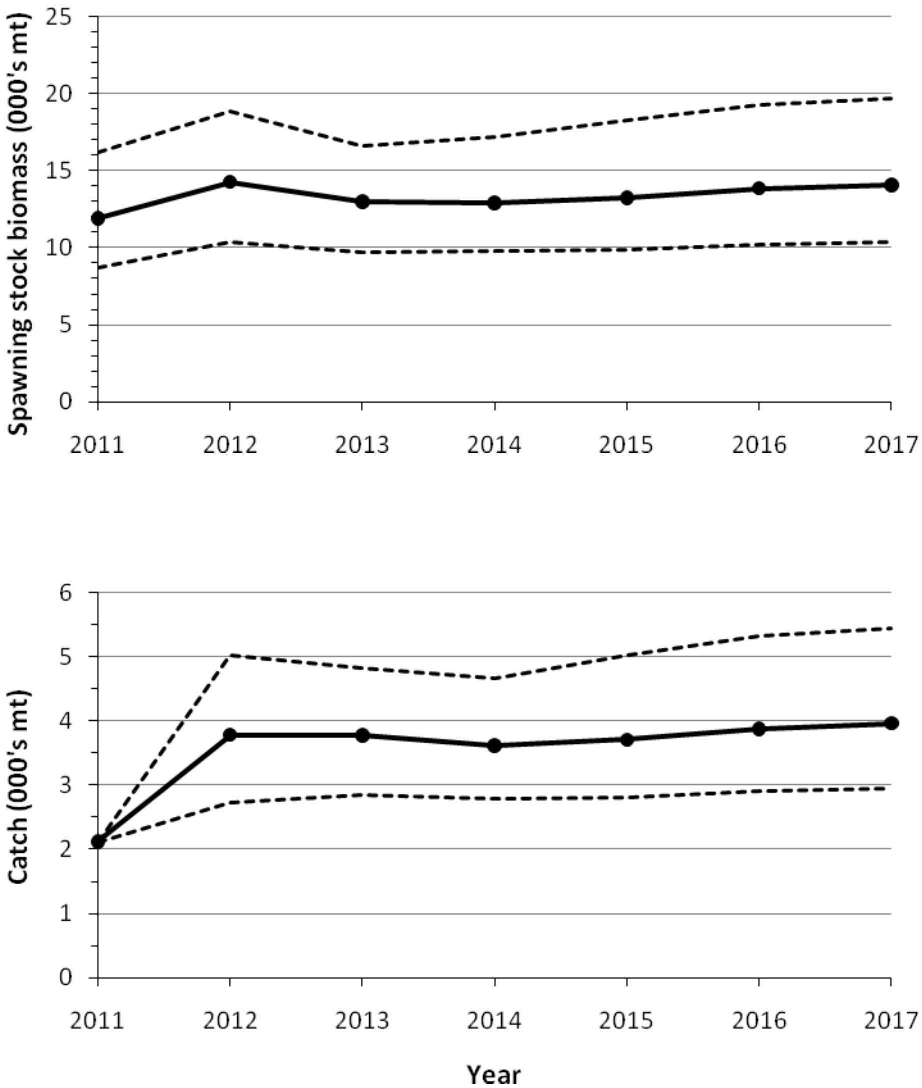


Figure B39. Projected median spawning stock biomass (000's mt, top panel) and catch (000's mt, bottom panel), for Georges Bank winter flounder during 2011-2017 (deadline year for rebuilding), based on a 2011 Annual Catch Limit of 2,118 mt and fishing at 75% of FMSY (= 0.315). SSBMSY = 11,800 mt. The dashed lines represent the 10% and 90% confidence intervals.

B. APPENDICES

Appendix B1. Southern Demersal Working Group meetings regarding the SARC 52 assessment of the three winter flounder stocks

The SDWG reviewed the data included in the stock assessments during April 19-21. The models were reviewed during April 26-28 and the reference points and remaining issues were reviewed during May 3-5, 2011 at the Northeast Fisheries Science Center in Woods Hole, MA. The following individuals attended one or more of the meetings:

Name	Affiliation	email
Paul Nitschke	NEFSC	paul.nitschke@noaa.gov
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Emilee Towle	NEFSC	emiliee.towle@noaa.gov
Katherine Sosebee	NEFSC	Katherine.sosebee@noaa.gov
Jay Burnett	Public	
Mark Wuenschel	NEFSC	mark.wuenschel@noaa.gov
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Richard McBride	NEFSC	richard.mcbride@noaa.gov
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Susan Wigley	NEFSC	susan.wigley@noaa.gov
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Scott Elzey	MADMF	scott.elzey@state.ma.us
Jeremy King	MADMF	jeremy.king@state.ma.us
Steve Cadrin	SMAST	scadrin@umassd.edu
Yuying Zhang	SMAST	yzhang2@umassd.edu
Anthony Wood	NEFSC	anthony.wood@noaa.gov
Dave Martins	SMAST	dmartins@umassd.edu
Larry Alade	NEFSC	larry.alade@noaa.gov
Gary Shepherd	NEFSC	gary.shepherd@noaa.gov
Jess Melgey	NEFMC	jmelgey@nefmc.org
Jim Weinberg	NEFSC	james.weinberg@noaa.gov
Paul Rago	NEFSC	paul.rago@noaa.gov
Lisa Kerr	SMAST	lkerr@umassd.edu
Maggie Raymond	Assoc. Fish. Maine	maggie.raymond@comcast.net
Mark Terceiro	NEFSC	mark.terceiro@noaa.gov

Appendix B2. Development of an environmentally explicit stock-recruitment model for three stocks of winter flounder (*Pseudopleuronectes americanus*) along the northeast coast of the United States

The objective of the analysis was to develop environmentally-explicit stock recruitment relationships for the three winter flounder stocks. For the Georges Bank stock, recruitment (lagged by 1 year) and spawning stock biomass pairs from the final VPA model were used in the analysis. Two general types of temperature data were used: air temperatures and coastal water temperatures (Appendix B2 Table 1). Air temperature data from the NCEP/NCAR Reanalysis (Kalnay et al. 1996) were used. This product combines observations and an atmospheric model to produce an even grid of atmospheric variables, in our case monthly mean surface air temperature. The spatial resolution is 2.5^o latitude by 2.5^o longitude. Air temperatures are closely related to estuarine water temperatures owing to efficient heat exchange in the shallow systems (Roelofs and Bumpus 1953, Hettler and Chester 1982, Hare and Able 2007). Data from representative grid points were averaged for each of three regions, and the monthly/regional averages were further averaged into annual estimates for three, two monthly periods (January-February, March-April, May-June).

Coastal water temperature data from Woods Hole, Massachusetts and Boothbay Harbor, Maine were used (see Nixon et al. 2004 and Lazzari 1997 respectively). Monthly means were calculated from mostly daily data. These monthly means were then averaged into annual estimates for the three, two monthly periods (January-February, March-April, May-June). The Woods Hole data were evaluated relative to the SNE/MA stock. Temperature data were analyzed as annual averages for three, two month periods (January-February, March-April, May-June). These two monthly periods capture temperature variability from the late winter, through spring and into early summer. The spring period was identified as important by Manderson (2008). The broader seasonal range was chosen because of potential differences in the timing of winter flounder spawning and development among the three stocks (Able and Fahay 2010) and the uncertainty as to the stage where recruitment is determined.

In addition to temperature, four large-scale forcing indices were included in the analyses. The North Atlantic Oscillation (NAO) is the dominant mode of winter climate variability in the North Atlantic region and has been related to numerous physical and biological variables across the North Atlantic (Ottersen et al. 2001, Visbeck et al. 2003). Brodziak and O'Brien (2005) identified a significant effect of NAO on recruit-spawner anomalies of winter flounder in the Gulf of Maine. The mechanism is unspecified, but NAO is related to estuarine water temperatures in the region (Hare and Able 2007). The winter NAO index is used here (Hurrell and Deser 2010). The Atlantic Multidecadal Oscillation (AMO) is a natural mode of climate variability and represents a detrended multi-decadal pattern of sea surface temperatures across the North Atlantic with a period of 60-80 years (Kerr 2005). Nye et al. (2009) found the AMO was strongly related to distribution shifts of fishes in the northeast U.S. shelf ecosystem. Finally, the Gulf Stream index is a measure of the northern extent of the Gulf Stream south of the northeast U.S. shelf ecosystem. The Gulf Stream position is related to the larger basin-wide circulation, which in turn is related to NAO and AMO. Work by Nye et al (in review) shows the Gulf Stream index has explanatory power for the distribution of silver hake in the system, possibly through the large-scale linkages between the Gulf Stream, Labrador Current and hydrographic conditions on the northeast U.S. shelf. Two Gulf Stream indices are used here (Joyce and Zhang 2010, Taylor and Stephens 1998).

The two indices differ in their calculation, with the Joyce and Zhang (2010) index more associated with the Gulf Stream south of the northeast U.S. shelf and the Taylor and Stephens (1998) index more associated with the Gulf Stream across the North Atlantic. For all four large-scale forcing indices, annual values were obtained. Numerous studies have found lagged effects of the NAO on the northeast U.S. shelf ecosystem (Greene and Pershing 2003, Hare and Kane in press). In particular, a two year lag has been related to the remote forcing of the NAO on the northeast U.S. shelf through the Labrador Current system. In addition, a zero year lag has been related to direct atmospheric forcing on the northeast U.S. shelf. Zero, one, and two year lags of were included for NAO and zero year lags were used for the other three large-scale forcing variables. To understand the relations between the host of 21 environmental variables, a simple correlation matrix was calculated. Significant correlations were considered in the context of previous research in the region. Significance was based on standard p-values; no corrections for multiple comparisons were made. The purpose was exploratory with an aim of understanding the relation between variables before incorporating them into stock recruitment functions.

Ricker, Beverton-Holt, and Cushing stock recruitment models were used with and without the different environmental terms. The model forms followed Levi et al. (2003), who built upon the ideas of Neill et al. (1994) and Iles and Beverton (1998). The fits of the three standard models were all very similar for the SNE/MA stock. Owing to the general acceptance of the Beverton-Holt model for use in stock-recruitment relationships and the overall similarity in the fits of the three models, here only the analyses using the Beverton-Holt model are presented. Environmental variables were assigned *a priori* for consideration with specific stocks. This was done to limit the number of environmentally-explicit stock recruitment relationships considered for each stock.

The standard stock-recruitment relationships were calculated first using the lsqcurvefit function in MatLab using the trust-region-reflective algorithm. A series of environmentally-explicit models also were fit using the same methods. The resulting models were compared using AICc and AICc weights, which represent the relative weight of evidence in favor of a model. The best environmentally-explicit model also was compared to the standard stock recruitment model using an evidence of weights procedure (Burnham and Anderson 2002). In this way the value of the environmentally-explicit stock recruitment functions relative to standard stock recruitment functions was judged. Model fitting included bounded parameters (or priors) to force realistic model forms.

Numerous relationships between environmental variables were evident based on the correlation analysis. The two Gulf Stream indices were related (r=0.54) but different enough to retain both in the analyses. Both Gulf Stream indices were related to the NAO with a 2 year lag (NAO leading). This relationship has been described before (Taylor and Stephens 1998). The Atlantic Multi-decadal Oscillation exhibited relatively little relationship with other variables. There was a negative relationship with the 2 year lagged NAO. The only strong positive correlation was found with Boothbay Harbor water temperatures. Both series exhibit a strong increasing trend over the time period considered. The North Atlantic Oscillation was related to the two Gulf Stream indices as already noted. NAO was not related to winter temperatures which may result from non-stationarity in the NAO-winter temperature relationship (Joyce 2002). Woods Hole temperature is closely related to regional air temperatures. This link is not surprising based on previous studies. Woods Hole temperature is also related to a lesser extent Boothbay Harbor temperatures. There is evidence of seasonal correlation in Woods Hole temperature, with values in January and February correlated to values in March and April, which in turn are correlated to values in May and June. However, the seasonal correlation is diminished after two months; temperatures in January and February are less related to temperatures in May and June. Boothbay Harbor temperature is strongly related to the AMO particularly in early summer. The lower magnitude of correlation with air temperatures compared to Woods Hole temperature is interesting and an explanation is lacking. It is possible that greater depths of coastal Maine increase the influence of oceanic factors and decreases the influence of atmospheric factors. The seasonal correlation described for Woods Hole temperatures in evident for Boothbay Harbor temperatures, but to a lesser degree.

The three air temperature series were all closely related indicating coherent air temperatures over the entire region. These analyses agree with the more comprehensive results of Joyce (2002). Correlations among regions over the same time (Jan-Feb) were higher than correlations within region between times (Gulf of Maine Jan-Feb compared to Gulf of Maine Mar-Apr). Seasonal correlation (Jan-Feb to Mar-Apr) were lower in the air temperature series compared to the water temperatures series as expected from the greater specific heat capacity of water.

The analyses suggest that the environmental forcing experienced by the three stocks differs in several important elements. The SNE/MA stock experiences coastal water temperatures that are strongly linked to local air temperatures. The GBK stock experiences water temperatures that are affected by both local air temperatures and more importantly, large-scale advective supply of relative cold, fresh water associated with the Labrador Current. Finally, the temperatures experienced by the GOM stock remain uncertain. If the Boothbay Harbor data is representative, then temperature is related to large-scale processes (AMO) and not local processes (air temperature). On the other hand, air temperature may be important, if early stage winter flounder are using shallower habitats.

Spawning stock biomass is comparable between the SNE/MA and GBK stock but recruitment is approximately four times greater for the SNE/MA stock at higher stock sizes (Appendix B2 Figure 1). The stock recruitment functions for the GBK and GOM stock are similar, with near constant recruitment over a relatively broad range of spawning stock biomasses. Recruitment on Georges Bank is estimated to be higher than in the Gulf of Maine at a given spawning stock biomass.

The residuals of the stock-recruitment relationships for the three stocks appear to exhibit synchrony through time (Appendix B2 Figure 2). Early in the time series, residuals between the stocks appear unrelated, but all residuals were positive in the mid 1990s and all were negative in the early 2000s. A formal analysis was conducted using serial correlation: calculating the correlation coefficient between two variables using a moving window. A similar analysis was used by Joyce (2002) to show that the relationship between NAO and east coast air temperatures has changed over the last 80 years and by Hare and Kane (in press) to show that the correlation between NAO and *Calanus finmarchicus* abundance has changed over the last twenty years. The serial correlation analysis demonstrated that early in the time series the residuals of the stock-recruitment functions were negatively or not correlated between the stocks (Appendix B2 Figure 3). Then, during the early 1990s, the residuals became positively correlated. The trend is most evident for the SNE/MA and GOM stocks and less so for these two stocks compared to the GBK stock.

The timing in the synchrony between the SNE/MA and GOM stocks is similar to the timing in synchrony among local populations within the SNE/MA stock (Manderson 2008). This synchrony suggests that some large-scale forcing is responsible for creating variance in the stock recruitment relationships of winter flounder across the northeast U.S. shelf ecosystem. The synchrony is greater between the SNE/MA and GOM stocks suggesting that the large-scale forcing has greater coherence along the coastal areas of the northeast compared to the offshore waters of Georges Bank.

Including an environmental term did not improve the stock recruitment relationship for the Georges Bank stock (Appendix B2 Table 2). The standard model was the best fit model and predicted near constant recruitment over the range of observations (Appendix B2 Figure 4). The evidence ratio of the best environmental model was 0.7 compared to the standard model (Appendix B2 Table 2). Environmental variables in the top 10 models included air temperatures, water temperatures and the Gulf Stream index, but these variables added no strength to the stock recruitment relationship (Appendix B2 Table 3). Importantly, the model fit, whether standard or environmental, was dependent on the priors imposed for the b term (Appendix B2 Table 4), which is related to but not identical to the steepness term (see Myers et al. 1999).

The environmentally-explicit models support the hypothesis that increased temperatures during spawning and the early life history result in decreased recruitment in the SNE/MA stock. Winter temperature is correlated with spring temperature providing a potential bridge between this study and that of Manderson (2007). Using the same serial correlation approach to examine trends in winter air temperature shows an increase in correlation among the three regions starting in the late-1980's early-1990's. The correlation coefficients of Southern New England and Gulf of Maine air temperatures are correlated with the similar coefficients for recruitment. This result suggests that as regional air temperatures have become more coherent, winter flounder recruitment in the coastal stocks also has become more coherent.

The results of the analyses support Manderson's (2008) earlier finding. Recruitment in coastal stocks of winter flounder is related to temperature during the spawning season. Importantly, recruitment is also dependent on spawning stock biomass and the environmentally-explicit stock-recruitment models capture the combined effect of environment and stock size. The temperature effect is strongest in the Southern New England stock, where the species is at the southern extent of its range. The signal is less pronounced in the Gulf of Maine, but recruitment is still linked to winter temperatures. The effect of environment on recruitment of Georges Bank winter flounder is less clear. There is a lot of variability in the stock-recruitment relationship and none of this variability is explained with the environmental terms considered here. Whether other environmental factors play a role in Georges Bank winter flounder recruitment is an important question requiring future research.

One use of the environmentally-explicit models is to develop short-term and long-term forecasting models. Based on the above analyses, there is no trend in winter temperature over the past 30 years and thus short-term forecasts can be developed using the environmentally-explicit models assuming winter temperatures to be at their mean state. It may also be useful to develop short-term forecasts under warm temperatures and short temperatures to provide managers with a tangible understanding of the effect of temperature on the stocks. The environmentally-explicit models could also be used to develop longer-term forecasts following the approach of Hare et al. (2010). These forecasts would provide an assessment of the sustainability of the winter flounder fishery on the 30-100 time scale.

Appendix B2 Table 1. Environmental variables used in the SDWG response to TOR 5 and their sources.

Variable	Abbreviation		Stocks	Source
Southern New England Air Temperature	aSNE	three 2 monthly periods	SNE	http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html
Georges Bank Air Temperature	aGB	three 2 monthly periods	GBK	http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html
Gulf of Maine Air Temperature	aGOM	three 2 monthly periods	GOM	http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html
Woods Hole Coastal Water Temperature	WH	three 2 monthly periods	GBK, SNE	http://www.nefsc.noaa.gov/epd/ocean/MainPage/ioos.html
Boothbay Harbor Coastal Water Temperature	BH	three 2 monthly periods	GOM	http://www.nefsc.noaa.gov/epd/ocean/MainPage/ioos.html
Atlantic Multidecadal Oscillation	AMO	0 year lag	GBK, GOM, SNE	http://www.cdc.noaa.gov/Correlation/amon.us.long.data
North Atlantic Oscillation (DJFM)	NAO	0, 1, and 2 year lags	GBK, GOM, SNE	http://www.cgd.ucar.edu/cas/jhurrell/Data/naodjfmindex.asc
Gulf Stream Index – Joyce and Zhang (2010)	GS-J	0 year lag	GBK GOM, SNE	Terry Joyce (pers. comm.)
Gulf Stream Index – Taylor and Stephens (1998)	GS-PLY	0 year lag	GBK, GOM, SNE	http://www.pml-gulfstream.org.uk/Web2009.pdf

Appendix B2 Table 2. Model weights, explained variance and evidence ratios for best environmentally-explicit models compared to best standard model.

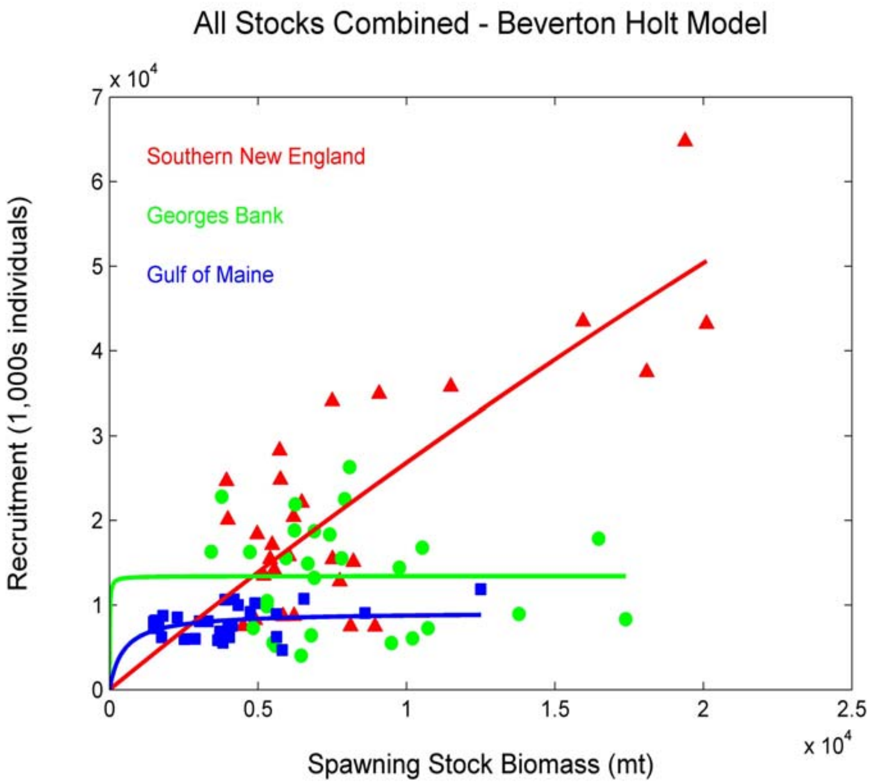
Stock	Model	Variable	W	r^2	Evidence Ratio
Southern New England	BH env M2	aSNE-JF	0.214	0.74	105.8
	BH std M	None	0.002	0.60	
Georges Bank	BH env M3	aGB-JF	0.057	0.07	0.7
	BH std M	None	0.082	0.00	
Gulf of Maine	BH env M2	aGOM-JF	0.108	0.21	2.2
	BH std M	None	0.003	0.07	

Appendix B2 Table 3. Akaike Information Criteria (AIC) statistics for the top ten ranked models for each stock.

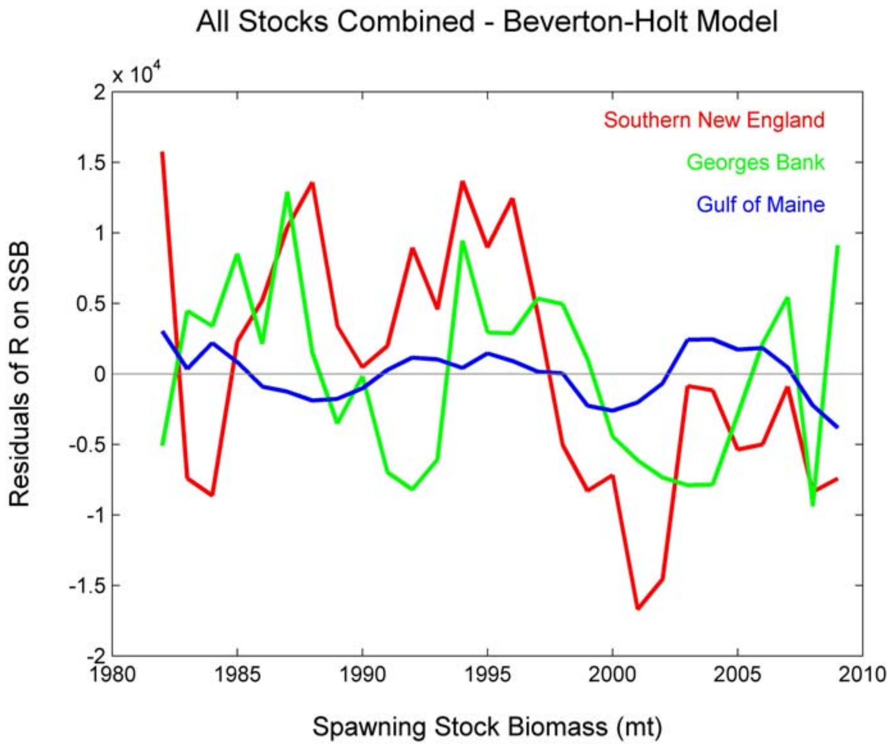
Stock	Model Rank	Model	Variable	AICc	delta	weight	cumulative weight
Southern New England	1	BH env M2	aSNE-JF	505.12	0.00	0.214	0.214
	2	BH env M2	GS-J-0	505.62	0.50	0.166	0.380
	3	BH env M1	aSNE-JF	505.79	0.66	0.153	0.533
	4	BH env M3	aSNE-JF	506.15	1.03	0.128	0.661
	5	BH env M2	AMO-0	507.47	2.35	0.066	0.727
	6	BH env M3	AMO-0	508.00	2.88	0.051	0.778
	7	BH env M1	AMO-0	508.05	2.93	0.049	0.827
	8	BH env M1	GS-J-0	509.17	4.05	0.028	0.855
	9	BH env M3	GS-J-0	509.21	4.09	0.028	0.883
	10	BH env M1	WH-JF	509.47	4.35	0.024	0.907
Georges Bank	1	BH std M	none	496.04	0.00	0.082	0.082
	2	BH env M3	aGB-JF	496.76	0.72	0.057	0.139
	3	BH env M1	aGB-MJ	496.95	0.91	0.052	0.191
	4	BH env M2	aGB-MJ	496.96	0.92	0.052	0.243
	5	BH env M3	GS-PML-0	497.29	1.25	0.044	0.287
	6	BH env M2	GS-J-0	497.55	1.51	0.039	0.326
	7	BH env M1	GS-J-0	497.56	1.51	0.039	0.365
	8	BH env M2	WH-MJ	498.04	2.00	0.030	0.395
	9	BH env M1	WH-MJ	498.06	2.02	0.030	0.425
	10	BH env M2	NAO-0	498.15	2.11	0.029	0.454
Gulf of Maine	1	BH env M2	aGOM-JF	423.39	0.00	0.108	0.108
	2	BH env M1	aGOM-JF	423.50	0.10	0.103	0.211
	3	BH env M2	aGOM-MJ	424.72	1.33	0.056	0.267
	4	BH env M2	BH-JF	424.83	1.44	0.053	0.320
	5	BH env M1	aGOM-MJ	424.84	1.45	0.052	0.372
	6	BH env M1	BH-JF	424.86	1.47	0.052	0.424
	7	BH std M	none	424.97	1.58	0.049	0.473
	8	BH env M2	aGOM-MA	425.04	1.64	0.048	0.521
	9	BH env M1	aGOM-MA	425.13	1.74	0.045	0.566
	10	BH env M3	BH-JF	425.63	2.24	0.035	0.601

Appendix B2 Table 4. List of standard and environmentally-explicit stock recruitment models used in the study. Formulation follows Levi et al. (2003).

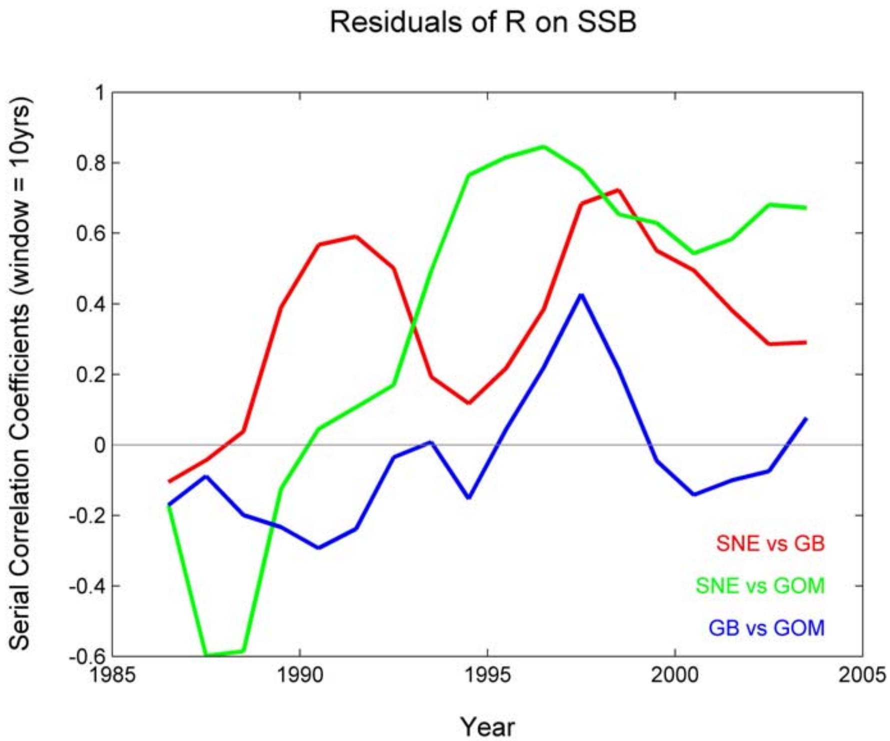
Model Name	Model Formulation	Model
Beverton-Holt	$R = S/(b + aS)$	Standard / No Environment
Beverton-Holt	$R = Se^{cE}/(b + aS)$	Environmental Model 1 Controlling Effects (alters the rate of change of numbers of young fish in time)
Beverton Holt	$R = S/(b + ae^{cE}S)$	Environmental Model 2 Limiting Effects (alters the carrying capacity of the habitat for recruits)
Beverton Holt	$R = S/(be^{cE} + aS)$	Environmental Model 3 Masking Effects (determines the metabolic work needed for the maintenance of the individual.)



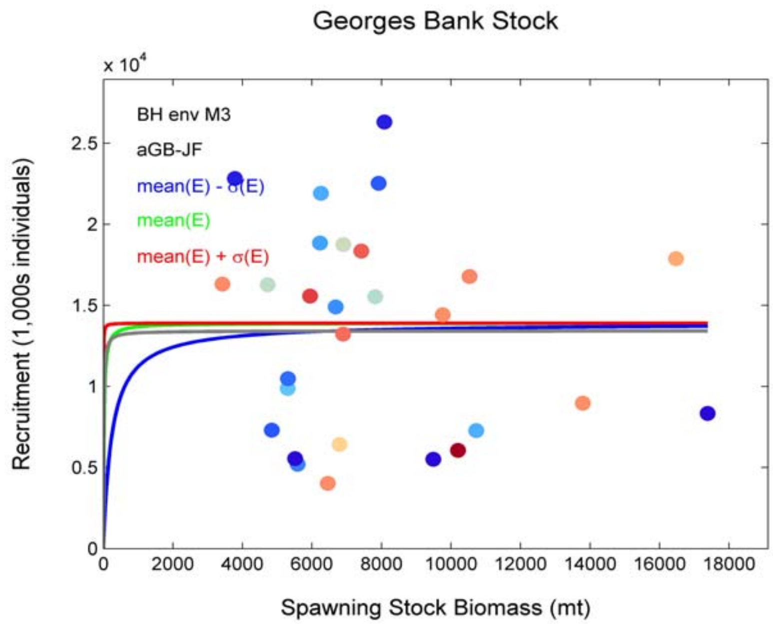
Appendix B2 Figure 1. Comparison of stock-recruitment data and standard Beverton-Holt stock-recruitment models for the three U.S. winter flounder stocks.



Appendix B2 Figure 2. Comparison of the residuals of the stock-recruitment relationships for the three U.S. winter flounder stocks based on the standard Beverton-Holt stock-recruitment model.



Appendix B2 Figure 3. Serial correlation of the residuals of the stock recruitment relationship making the three pairwise comparisons: SNE vs. GB, SNE vs. GOM, and GB vs. GOM. Window for serial correlations set at 10 years.



Appendix B2 Figure 4. Environmentally-explicit stock recruitment relationships for Georges Bank winter flounder. The best overall environmental model is shown as is the standard model (gray). Symbols are color coded to the value of the environmental variable and model predictions for mean environment and ± 1 standard deviation of the environmental variable are shown. The specific models and environmental variables are noted in the upper left hand corner (see Appendix B2 Tables 1 and 2).

Appendix B3. Estimation of length-based vessel calibration factors

The Survey Research Vessel (SRV) *Albatross IV* (Albatross) was replaced in 2009 by the SRV *Henry B. Bigelow* (Bigelow) as the main platform for NEFSC research surveys, including the spring and fall bottom trawl surveys. The size, towing power, and fishing gear characteristics of the Bigelow are significantly different from the Albatross, resulting in different fishing power and therefore different survey catchability. Calibration experiments to estimate these differences were conducted during 2008 (Brown 2009), and the results of those experiments were peer-reviewed by a Panel of independent (non-NMFS) scientists during the summer of 2009 (Anonymous 2009, Miller et al. 2010). The terms of reference for the Panel were to review and evaluate the suite of statistical methods used to derive calibration factors by species before they were applied in a stock assessment context. Following the advice of the August 2009 Peer Review (Anonymous 2009), the combined-seasons ratio estimator calibration factors were initially adopted to convert Bigelow survey catch number and weight indices to Albatross equivalents. The aggregate catch number calibration factor for winter flounder, for combined seasons, is 2.490 and the aggregate catch weight factor, for combined seasons, is 2.086.

Since the 2009 Peer Review, it has become evident that accounting for size of individuals can be important for many species. If there are different selection patterns for the two vessels for a given species, the ratio of the fractions of the fish caught by the two vessels can vary with size. Since 2009, length-based calibration factors have been estimated for several stocks (cod, haddock, and yellowtail flounder through the Trans-boundary Resource Assessment Committee [TRAC] assessment process; silver, offshore, and red hakes during the 2010 SARC 51 and *Loligo* squid during the 2010 SARC 51 (Brooks et al. 2010, NEFSC 2011). For those length-based calibrations, the same basic beta-binomial model from Miller et al. (2010) was assumed, but various functional forms were assumed for the relationship of length to the calibration factor. Since then, Miller (submitted) has explored two types of smoothers for the relationship of relative catch efficiency to length and the beta-binomial dispersion parameter. The smoothers (orthogonal polynomials and thin-plate regression splines) allow much more flexibility than the functional forms previously considered for other stocks by Brooks et al. (2010) and NEFSC (2011).

The SDWG reviewed work by Miller (MS 2011) on winter flounder in greater detail, and compared the model results for all winter flounder to those from a model that accounted for effects of stock area (GOM, GBK, and SNE/MA). The SDWG also explored seasonal effects, but did not fully pursue those models due to a lack of samples in the Gulf of Maine stock region during the spring. The lead assessment scientists for each of the winter flounder stocks compared predicted indices in Albatross units based on the different fitted models to explore the degree of consistency between calibrated indices using the different models.

When fitting the fourth order polynomial with smoother models to data from each stock region, there were convergence issues for the GOM stock data, likely due to over-parameterization of the length effects. When the order of the polynomial was reduced to two for this region, these issues were resolved. The resulting model performed better than the best models that Miller (submitted) fit that did not account for effects of stock area. Inspection of residuals revealed no strong trend with predicted number captured by the Bigelow or total number captured by station and no strong departure from normality. The predicted relative catch efficiency was lowest at intermediate size classes for all three stock areas, but the location of the minimum was at larger size for the Georges Bank stock than for the two other stock areas.

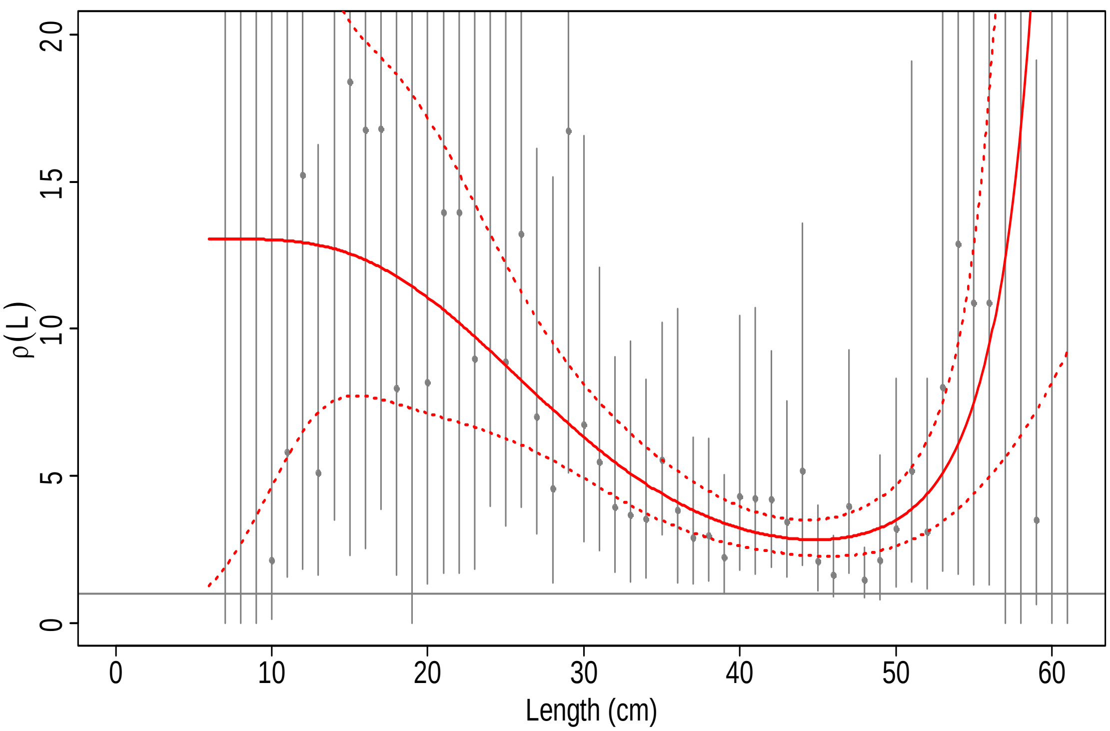
When applying the relative catch efficiencies to surveys conducted in 2009 and 2010 with the Bigelow, there is an important caution to note. Lengths may be observed in these surveys that are outside of the range of lengths observed during the calibration study. This problem is exacerbated when the data are subset by stock area for the estimation of relative catch efficiency, because the limits of the range of sizes available in the subsets can be narrower than the range of the entire data set, and so caution must be taken in predicting catches in Albatross units at these sizes. The SDWG also had some concerns with the asymptotically increasing estimates of relative catch efficiencies at the smallest and largest sizes for the winter flounder stocks, particularly when converting historic Albatross indices to Bigelow equivalents. Sizes of fish outside of the ranges observed during the calibration study (7-61 cm for the Georges Bank stock) would potentially lead to extremely high Bigelow abundance indices at the extremes of the length composition for the historic data In order to address this concern, an adaptation of the model was explored that constrained lengths beyond a minimum and maximum length to have constant relative catch efficiencies. The minima and maxima were determined by specifying a maximum coefficient of variation (CV) of predicted relative catch efficiencies at these lengths. These CV criteria resulted in models that provided aggregate abundance indices that were very similar to the corresponding models without the CV criteria. Because no ad-hoc CV criteria were necessary in the initial regional length models, the SDWG found those to be preferable.

Lastly, the swept areas for each tow during the 2009 and 2010 surveys would ideally be used to predict Albatross catches at each station, but if there is little variability in the swept areas, a mean can be used and the mean number per tow at length in Bigelow units can be converted to Albatross units. The fourth order polynomial model fit to data for the Georges Bank stock region, incorporating a mean ratio of the vessel swept areas of 0.5505 (Bigelow to Albatross), was used to calculate the calibration factors-at-length (Appendix B3 Figure 1) that were used to convert the 2009-2010 Bigelow survey indices to Albatross units for use in population model calibration (Appendix B3 Table 1).

Appendix B3 Table 1. NEFSC spring and fall survey indices from the SRV *Henry B. Bigelow* (HBB) and length-calibrated, equivalent indices for the SRV *Albatross IV* (ALB) time series. Indices are the sum of the stratified mean numbers (n) at length. Spring and fall strata sets include offshore strata 13-23. The length calibration factors are for the Georges Bank stock region for the lengths observed in the calibration experiment (7-61 cm) and include a constant, swept area factor of 0.5505. The effective total catch number calibration factors vary by year and season, depending on the characteristics of the Bigelow length frequency distributions.

Year	Spring (n) HBB	CV	Spring (n) ALB	Effective Factor
2009	8.600	51.9	2.683	3.204
2010	5.063	28.0	2.085	2.428

Year	Autumn (n) HBB	CV	Autumn (n) ALB	Effective Factor
2009	14.220	26.8	6.578	2.162
2010	5.298	36.3	2.380	2.226



Appendix B3 Figure B1. Relative catch efficiency of Georges Bank winter flounder from a beta-binomial model where relative catch efficiency was modeled as an orthogonal polynomial smoother of length (solid red line) and from separate models fit to catch data in each length class (gray points). The dashed red lines and vertical gray lines represent approximate 95% confidence intervals. The horizontal gray line represents equal efficiency of the SRVs *Henry B. Bigelow* and *Albatross IV*.

C. Gulf of Maine (GOM) WINTER FLOUNDER STOCK ASSESSMENT FOR 2011

[SAW52 Editor's Note: The SARC-52 peer review panel concluded that no ASAP model run provided a suitable basis for management advice. A swept-area biomass method was accepted instead, and it is described in Appendix C1.]

The Southern Demersal Working Group (SDWG) prepared the stock assessment. The SDWG met during April 19-21, April 26-28, and May 3-5, 2011 at the Northeast Fisheries Science Center, Woods Hole, MA, USA.

The following participated in all or part of the meetings:

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SAW 52 Terms of Reference

C. Winter flounder (Gulf of Maine Stock)

1. Estimate catch from all sources including landings and discards. Characterize the uncertainty in these sources of data.

2. Present survey data being considered and/or used in the assessment (e.g., regional indices of abundance, recruitment, state and other surveys, age-length data, etc.). Characterize uncertainty in these sources of data.

3. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series (integrating results from TOR-5), and estimate their uncertainty. Include area-swept biomass estimates. Investigate if implied survey gear or catchability estimates are reasonable. Include a historical retrospective analysis to allow a comparison with previous assessment results.

4. Perform a sensitivity analysis which examines the impact of allocation of catch to stock areas on model performance (in TOR-3).

5. Examine the effects of incorporating environmental factors in models of population dynamics (e.g., spring water temperatures in an environmentally-explicit stock recruitment function).

6. State the existing stock status definitions for “overfished” and “overfishing”. Then update or redefine biological reference points (BRPs; point estimates or proxies for BMSY, BTHRESHOLD, and FMSY) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the “new” (i.e., updated, redefined, or alternative) BRPs.

7. Evaluate stock status (overfished and overfishing) with respect to the “new” BRPs (from TOR 6), and with respect to the existing BRPs (from a previous accepted peer review) whose values have been updated.

8. Develop and apply analytical approaches and data that can *be used for conducting* single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs) under a set of alternative harvest scenarios. If the stock needs to be rebuilt, take that into account in these projections.

a. Provide numerical short-term projections (3-5 yrs, or through the end of the rebuilding period, as appropriate). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions about the most important uncertainties in the assessment (e.g., terminal year abundance, variability in recruitment).

b. Take into consideration uncertainties in the assessment and the species biology to describe this stock's vulnerability (see "Appendix to the SAW TORs") to becoming or remaining overfished, and how this could affect the choice of ABC.

c. Develop plausible hypotheses (e.g., mixing among the three stocks) which might explain any conflicting trends in the data and undertake scenario analyses to evaluate the consequences of these alternate hypotheses on ABC determination.

9. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

Executive Summary

1. Estimate catch from all sources including landings and discards. Characterize the uncertainty in these sources of data.

Commercial landings were near 1,000 mt from 1964 to the mid 1970s. Thereafter commercial landings increased to a peaked of 2,793 mt in 1982, and then steadily declined to 350 mt in 1999. Landings have been near 650 mt from 2000 to 2004 and about 300 mt from 2005 to 2009. Landings have declined to a record low of 140 mt in 2010. Recreational landings reached a peak in 1981 with 2,554 mt but declined substantially thereafter. Recreational landings have generally been less than 100 mt since 1994, with exception of 2008 were the landings was estimated at 103 mt. A discard mortality of 15% was assumed for recreational discards. Discards were estimated for the large mesh trawl (1982-2010), gillnet (1986-2010), and northern shrimp fishery (1982-2010). A discard mortality of 50% was assumed for commercial fishery. In general the total discards are a small percentage (time series average 11%) of the total catch. There has been a substantial decline in the total catch compared to the early 1980s (recent catch is roughly 5% of the 1980s catch).

2. Present survey data being considered and/or used in the assessment (e.g., regional indices of abundance, recruitment, state and other surveys, age-length data, etc.). Characterize uncertainty in these sources of data.

The spring and fall NEFSC, Massachusetts DMF (MDMF) and the Maine New Hampshire (MENH) surveys were used in the Gulf of Maine winter flounder assessment. In general the survey indices are relative flat over the time series in comparison to the catch trends. All of the indices generally show a slight decrease in the population in the late 1980s from a high in the early 1980s with low abundance remaining through the early 1990s. All of the indices show signs of increase abundance starting in 1998 and 1999. Since 2001 all indices indicate some decrease in abundance. However there have been recent increases in the indices at age for the older fish. Length base conversions were use in 2009 and 2010 when the new survey vessel was used in the NEFSC survey.

The SARC accepted GOM winter flounder assessment is based on an empirical swept-area model utilizing data from the 2010 NEFSC fall survey, the MADMF fall survey, and the Maine-New Hampshire fall inshore surveys. Using an efficiency value of 0.6 the estimated stock biomass in 2010 of fish greater than 30 cm was 6,341 mt (80% CI 4,230 - 8,800 mt) (Appendix C1).

3. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series (integrating results from TOR-5), and estimate their uncertainty. Include area-swept biomass estimates. Investigate if implied survey gear or catchability estimates are reasonable. Include a historical retrospective analysis to allow a comparison with previous assessment results.

The base and split VPA were updated from the GARM III assessment. The SDWG changed the *assumed natural mortality from 0.2 to 0.3 in this assessment. Diagnostics still imply major sources for concern surrounding the VPA model formulation for GOM winter flounder. The SDWG developed a new assessment in ASAP (Age Structured Assessment Program) which provides more flexibility in the weighting of data sources. The population models have difficulty with the conflicting data trends within the assessment, specifically the large decrease in the catch over the time series with very little change in the indices or age structure in both the catch and surveys. The scaling of the population estimates was sensitive to the weight imposed on the catch at age compositions. The ASAP model allowed errors in the fit to the catch at age and improved fit to the survey indices without the split. However this resulted in a lack of fit to the plus group in the catch at age composition. The combined survey 30+ biomass area swept estimate was used to inform the optimal weighting for the preferred model formulation. The resulting final SDWG model weighting formulation considered both the tradeoff between retrospective bias and feasible biomass estimates at the end of the time series. The within model uncertainty did not capture the uncertainty in this assessment considering how sensitive the results were to the model formulation and weighting.* ***The SARC concluded that the ASAP assessment model was too unreliable to be a basis for management.***

The accepted assessment of GOM winter flounder stock is based on an empirical swept-area model utilizing data from the 2010 NEFSC fall survey, the MADMF fall survey, and the Maine-New Hampshire fall inshore surveys. Using an efficiency value of 0.6 the estimated stock biomass in 2010 of fish greater than 30 cm was 6,341 mt (80% CI 4,230 - 8,800 mt). Exploitation rate in 2010 was estimated at 0.03 (80% CI 0.02 - 0.05) based on the ratio of 2010 catch (195 mt) to survey based swept area estimate of biomass for winter flounder exceeding 30 cm in length (6,341 mt). The biomass estimate for 2010 is 16% lower than that for 2009 using the same survey methods but this difference is not statistically significant (Appendix C1).

4. Perform a sensitivity analysis which examines the impact of allocation of catch to stock areas on model performance (in TOR-3).

The SDWG interpretation of TOR4 is that the variance of the commercial landings due to the 1995 and later area-allocation scheme should be used as the basis for the magnitude of landings that might be lost or gained from the stock-specific assessments, and then perform an exercise to run the assessment model with those potential biases and report the results. Additional work was done to estimate the error in the commercial landings due to misreporting of commercial landings to statistical area at allocation level A. Given the magnitude of these errors, the SDWG elected to run the final GOM winter flounder ASAP model, with an additional 5% PSE in commercial landings added to the estimated PSE over the 1995-2010 time series.

The commercial landings have a calculated Proportional Standard Error (PSE; due to the commercial landings area-allocation procedure; available for 1995 and later years, with the mean of those years substituted for 1982-1994) ranging from 5.3% to about 6.5%; the commercial discard (trawl and gillnet) PSEs range from 16-177% (available for 1994-2010, mean of those years substituted for 1982-1993); and the recreational landings PSEs range *from 17-50%. Because the PSEs for the commercial landings are low, and the commercial landings account for about two-thirds of the total catch, the total catch weighted-average annual PSEs range from 7-30%, and averages 11.7% (unweighted) for the 1981-2010 time series.*

The catch in the final assessment model was increased and decreased by the annually varying PSE and models were re-run to provide an additional measure of uncertainty of assessment estimates. For the final ASAP multi model, the fishing mortality estimate in 2010 did not change greatly (0.01 to 0.034). The 2010 SSB range was 4,700 to 6,900 mt, was similar to the MCMC estimate of uncertainty. However the assessment modeling was not accepted by the SARC as a basis for management.

5. Examine the effects of incorporating environmental factors in models of population dynamics (e.g., spring water temperatures in an environmentally-explicit stock recruitment function).

To develop environmentally-explicit stock recruitment relationships, three specific types of data are required: spawning stock biomass, recruitment, and environmental data. Spawning stock biomass and recruitment data from the final 2011 SAW 52 assessment models were used in the analysis. For the GOM stock, recruitment (lagged by 1 year) and spawning stock biomass pairs were used from the ASAP multi model. Two general types of temperature data were used: air temperatures and coastal water temperature. In addition to temperature, four large-scale forcing indices were included in the analyses. The North Atlantic Oscillation (NAO) is the dominant mode of winter climate variability in the North Atlantic region and has been related to numerous physical and biological variables across the North Atlantic (Ottersen et al. 2001, Visbeck et al. 2003). The Atlantic Multidecadal Oscillation (AMO) is a natural mode of climate variability and represents a detrended multi-decadal pattern of sea surface temperatures across the North Atlantic with a period of 60-80 years (Kerr 2005). Finally, the Gulf Stream index is a measure of the northern extent of the Gulf Stream south of the northeast U.S. shelf ecosystem. The Gulf Stream position is related to the larger basin-wide circulation, which in turn is related to NAO and AMO. Two Gulf Stream indices are used here (Joyce and Zhang 2010, Taylor and Stephens 1998).

For the Gulf of Maine stock, increased winter air temperatures are related to lower recruitment, but the strength of this environmental forcing is less than for the Southern New England stock. This result makes sense in the context of the distribution of winter flounder; the southern stock is most affected by warmer temperatures.

One use of the environmentally-explicit models is to develop short-term and long-term forecasting models. Based on this work, there is no trend in winter temperature over the past 30 years and thus short-term forecasts can be developed using the environmentally-explicit models assuming winter temperatures to be at their mean state. It may also be useful to develop short-term forecasts under warm temperatures and short temperatures to provide managers with a tangible understanding of the effect of temperature on the stocks. The environmentally-explicit models could also be used to develop longer-term forecasts following the approach of Hare et al. (2010). These forecasts would provide an assessment of the *sustainability of the winter flounder fishery on the 30-100 time scale. Work is underway within the SDWG to incorporate environmentally-explicit stock-recruitment models into the NFT standard software used to fit stock-recruitment models and to perform projections of stock and fishery catch. However, this work has not been developed sufficiently to be made available for peer-review at this time (see new Research Recommendation 10).*

6. State the existing stock status definitions for "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; point estimates or proxies for BMSY, BTHRESHOLD, and FMSY) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

The 2008 GARM III assessment was not accepted and the overfished and overfishing status of the GOM winter flounder stock is currently unknown. For the new 2011 assessment, the SDWG split VPA estimated higher percent maximum spawning potential (MSP) proxies relative to the ASAP model because the VPA estimated selectivity was shifted to older fish. The SDWG ASAP multi run estimated a F40% FMSY proxy at 0.34 using the 2006-2010 average mean weights and selectivity as input to the YPR analysis. The F40% SSBmsy was estimated from a long term projection (100 years) using the CDF of recruitment from the entire model time series (1982-2010) and the estimated YPR F40%. The SSBmsy using the FMSY = F40% proxy was estimated at 3,287 mt with a SSBmsy threshold estimate of 1,644 mt and MSY equal to 1,080 mt for the ASAP multi run. The Beverton Holt stock recruitment Fmsy using the Pleuronectids steepness prior from Myers et al. (1999; 0.8 mean and CV = 0.09) was estimated at 0.57. The stock recruit SSBmsy was estimated at 2,167, SSBmsy threshold = 1,084 mt, and MSY = 1,152. The MSY estimates did not vary greatly with SSBmsy from the mcmc in the stock recruitment analysis. The SDWG expressed concern with the stock recruitment estimate of SSBmsy being estimated in the lower end of the range of past SSB observations. However SARC 52 did not accept the SDWG model and the overfished status remains as unknown since biomass based reference points could not be estimated.

The SARC accepted a proxy value of the overfishing threshold which was derived from a length-based yield per recruit analysis that assumes all fish above 30 cm are fully recruited to the fishery and that natural mortality is 0.3. Using $F_{40\%}$ (0.31) as a proxy for Fmsy, the threshold exploitation rate is 0.23 and 75%$F_{40\%}$ exploitation was 0.17 with M=0.3. The reference points were converted to exploitation rates to be consistent with the swept area biomass approach.

7. Evaluate stock status (overfished and overfishing) with respect to the "new" BRPs (from TOR 6), and with respect to the existing BRPs (from a previous accepted peer review) whose values have been updated.

The 2008 GARM III assessment was not accepted and the overfished and overfishing status of GOM winter flounder stock is currently unknown. In the new 2011 assessment, stock status evaluation was consistent regardless of the model formulation (VPA and ASAP). Both the split

VPA model and the SDWG preferred ASAP multi model indicate that the stock is not overfished and overfishing is not occurring. However spawning stock biomass relative to the SSBmsy varied widely between the VPA and preferred ASAP multi model. SSB in 2010 to SSBmsy ratios varied from the stock recruit Split VPA estimate of 0.52 to the stock recruit estimate of 3.09 from the ASAP multi with no prior on steepness. All models show that fishing mortality in 2010 were well below their respective Fmsy reference points. Fishing mortality in 2010 to Fmsy ratios varied from the stock recruitment split VPA ratio estimate of 0.47 to the stock recruitment estimated ratio of 0.05 from the ASAP multi run with no prior on steepness. The SDWG ASAP multi run using the Fmsy = F40% proxy estimated the SSB2010/SSBmsy ratio at 1.77 and the F2010/F40 at 0.09. The stock recruitment priors did lower the estimated steepness which lowered the SSB2010/SSBmsy ratio to 2.74 and increased the F2010/Fmsy ratio to 0.06.

All GOM winter flounder models have diagnostic issues due to the conflicting signals in the data. The SDWG preferred the ASAP multi model as the best fit to all data sources including considerations for reasonable estimates of biomass in 2009 and 2010 in comparisons to the survey area swept biomass estimates. However the SDWG questioned the feasibility of the estimated SSB relative to the SSBmsy reference points for both the F40% proxy and the stock recruit estimates (1.77 to 2.68). In general the trends and biomass estimated by the model seem appropriate. Surveys and anecdotal feedback from fishermen suggest a shift in the population to deeper water which can help explain the lack of catch in the recreational fishery. However questions remain with the lack of higher catches as the stock rebuilds during the late 1990s and early 2000s when effort in the groundfish fishery was high. In addition, there is little evidence of a change in the size structure or stock range expansion to waters off the coast of Maine which traditionally had higher catches. Considerable uncertainty remains with regards to the comparison of the 2010 SSB relative to the SSBmsy biological reference points. The SARC concluded that the population models are too uncertain as a based from stock status determination.

The overfished status remains as unknown since an analytical model was not accepted and a biomass reference point could not be estimated. *The SARC concluded that in 2010 overfishing was not occurring for the stock. A proxy value of the overfishing threshold was derived from a length-based yield per recruit analysis that assumes all fish above 30 cm are fully recruited to the fishery and that natural mortality is 0.3. Using F40% (0.31) as a proxy for Fmsy, the threshold exploitation rate is 0.23. Exploitation rate in 2010 was estimated at 0.03 (80% CI 0.02 - 0.05) which was based on the ratio of 2010 catch (195 mt) to survey based swept area estimate of biomass for winter flounder exceeding 30 cm in length (6,341 mt).*

8. Develop and apply analytical approaches and data that can be used for conducting single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs) under a set of alternative harvest scenarios. If the stock needs to be rebuilt, take that into account in these projections.

a. Provide numerical short-term projections (3-5 yrs, or through the end of the rebuilding period, as appropriate). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions about the most important uncertainties in the assessment (e.g., terminal year abundance, variability in recruitment).

SDWG Ten year AGEPRO projections assumed that the ACL of 230 mt will be taken in 2011. Projections were done using 1000 bootstrap iterations from the split VPA and 1000 mcmc iterations from the preferred ASAP multi run. SSB, catch, and fishing mortality with 80 confidence intervals were estimated from the split VPA at the Fmsy proxy of F40% = 0.43 (derived from the updated split VPA) and 75% of the F40% proxy = 0.32. Projections for the ASAP multi model were also run assuming the F40% proxy = 0.34 and 75% of the F40% = 0.26. Short term projections using the stock recruit reference point with the prior on steepness for the ASAP multi run were also done at Fmsy = 0.57 and 75%Fmsy = 0.42. All projections show relatively high catch in 2012 compared to model time series of catches. The projected VPA SSB increases towards SSBmsy after lower estimates of SSB in 2013 and 2014. The low SSB estimate in 2013 and 2014 is due to the low recruitment estimated in 2009 and 2010 which was influenced by the length based survey calibration. Therefore substantial uncertainty exists with the estimated recruitment in 2009 and 2010. The ASAP multi short term projections result in fishing of the SSB down to SSBmsy. The estimated catch in 2012 shows a large increase relative to the assumed catch in 2011 of 230 mt for both the split VPA and ASAP formulations. The ASAP multi run estimated 2012 catch varies from 1,700 mt from the 75% F40 projection to the stock recruit Fmsy projection estimate of 3,080 mt. However catch declines quickly after 2012 as the stock approaches SSBmsy. Consideration could be given to the overestimation of the plus group in the ASAP model projections. For example a plus group residual adjustment within AGEPRO can be approximated using an assumed plus group discard proportion.

The SARC did not accept the analytical modeling. Therefore projections are not possible.

b. Take into consideration uncertainties in the assessment and the species biology to describe this stock’s vulnerability (see “Appendix to the SAW TORs”) to becoming or remaining overfished, and how this could affect the choice of ABC.

Uncertainties that were not accounted for by assessment and reference point models were evaluated using model diagnostics. Standard model diagnostics (e.g., residual analyses, retrospective analyses) were used for model validation. Vulnerabilities that were not accounted for by assessment and reference point models were evaluated using exploratory modeling, habitat observations and testing the influence of environmental factors on recruitment dynamics. Additional considerations of vulnerability and productivity are the implications of shifts in distribution, recruitment dynamics and increased natural mortality. Nye et al. (2009) found an annual increase in mean depth (0.8 m per year) of the winter flounder distribution, which may have productivity and vulnerability implications. Apparent decreases in estuarine spawning or shifts toward coastal spawning (e.g., DeCelles and Cadrin 2010) may also have implications for vulnerability (e.g., less availability to recreational fisheries) and productivity (less larval retention). Consumption of winter flounder by other fishes, birds and mammals may be increasing as these predator populations increase. The GOM assessment indicates that the stock is well above B_{MSY} *and experiencing low fishing* *mortality. However, the GOM assessment is the most uncertain of the three (from a "feasibility" perspective, if not from a "statistical precision" perspective). The apparent shift in distribution to deeper habitat may be adding uncertainty to the stock assessment reference points that assume stationarity in vital rates. Therefore, it may be vulnerable to overfishing if managed at a catch level close to the nominally projected catch in the near term.*

c. Develop plausible hypotheses (e.g., mixing among the three stocks) which might explain any conflicting trends in the data and undertake scenario analyses to evaluate the consequences of these alternate hypotheses on ABC determination.

Major conflicting signals exist between the catch at age data and survey data within the modeling work. The split VPA is weighted towards the catch at age information while the preferred ASAP multi run has a greater weight on the survey information. Survey trends may not reflect the population changes in response to the large decline in the catch over time if a greater proportion of the population historically remained within the estuaries in the early 1980s where there is no survey coverage. This hypothesis could possible explain why the survey indices are relatively flat with little apparent response to the change in catch. However there is very limited data on the extent of estuarine residing populations in the 1980s. Therefore this hypothesis remains simply as speculation. The consequences of the split VPA being a better reflection of the true dynamics can be evaluated by assuming the catch or ABC from the preferred ASAP projection is taken within the split VPA projection formulation.

9. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

About ten of the previous fourteen research recommendations have been partially addressed. Twelve new research recommendations have been developed by the SDWG for SAW52.

Introduction and Assessment History

Gulf of Maine winter flounder is the smallest of the three winter flounder stocks (Figure C1). Gulf of Maine winter flounder was first assessed in SARC 21 (1995) as an index based assessment. It was noted at that assessment that survey indices were low and relatively few large fish were seen in the survey size distributions. Survey Z estimates were high (1978-1993 mean of 1.21) and the stock was thought to be overexploited. The SARC 36/GARM 1 assessment in 2001 was the first analytical assessment (ADAPT VPA) for this stock. The stock was considered rebuilt and overfishing was not occurring. In GARM II the ADAPT VPA model was updated through 2004 (NEFSC 2005). The GARM II assessment also concluded that the stock is not overfished and overfishing is not occurring. Spawning stock biomass was estimated to be at 3,400 mt and fully recruited F = 0.13 in 2004. SSB at B_{msy} was estimated to be at 4,100 mt and F_{msy} = 0.43. The GARM II VPA developed a severe retrospective pattern in F and a large overestimation of SSB. GARM II concluded that VPA results were too uncertain as a basis for performing projections.

In GARM III the review panel was unable to determine the stock's status relative to the BRPs, but stated that trends in the population were very troubling (NEFSC 2008). The Review Panel generally agreed that the stock biomass was highly likely to be less than the B_{MSY} proxy, and that there is a substantial probability that it was below the minimum stock size threshold. The split VPA model estimated spawning stock biomass in 2007 at 1,100 mt or about 29% of the B_{MSY} proxy (3,792 mt) and fishing mortality in 2007 was 0.42 or about 147% of $F_{40\%} = 0.28$. The base case VPA and a split forward projection model (SCALE) which put higher weight on the recruitment indices suggested that the stock was not overfished and overfishing was not occurring. However the base case VPA had a severe retrospective pattern. The VPA showed greater reductions in biomass than observed in the survey biomass trends. All models had difficulty fitting the relatively flat age 1 and age 2 recruitment indices and the decrease in adult indices with the large decline in the catch at the end of the time series. The models were not accepted as a basis for status determinations. Therefore the stock status is unknown.

TOR 1: Estimate catch from all sources including landings and discards. Characterize the uncertainty in these sources of data.

Commercial landings were near 1,000 mt from 1964 to the mid 1970s. Thereafter commercial landings increased to a peaked of 2,793 mt in 1982, and then steadily declined to 350 mt in 1999. Landings have been near 650 mt from 2000 to 2004 and about 300 mt from 2005 to 2009. Landings have declined to a record low of 140 mt in 2010 (Table C1, Figure C2). The primary gear used was the otter trawl from 1964-1985 that accounted for an average of 95% of the landings. Otter trawl accounted for an average of 74% of the landings from 1986- 2010 with an increase in the proportion of the landings coming from gillnets (26% from 1986-2010) (Table C2). Since 1999 around 95% percent of the landings are taken in Massachusetts from statistical area 514 (Figures C3 and C4). Winter flounder are landed throughout the year. However a greater proportion of the landings have been coming from quarter three over the last ten years (Figure C4). The proportion of the landings coming from the medium market category has decreased since 2004 (Figures C4).

Recreational landings reached a peak in 1981 with 2,554 mt but declined substantially thereafter (Table C4, Figure C5). Recreational landings have generally been less than 100 mt since 1994, with exception of 2008 were the landings was estimated at 103 mt. The PSE of the recreational landing averaged 29% over the time series. Recreational landing weight was re-estimated using the expanded numbers at length and the length weight relationship by half year for input to the VPA, SCALE, and ASAP models.

In the commercial fishery, annual sampling intensity varied from 6 to 310 mt landed per sample during 1982-2007. Overall sampling intensity was adequate, however temporal and market category coverage in some year was poor (Table C4). Samples were pooled by half year when possible. In 1982 mediums were pooled with unclassified by half year, in 1985, 1995, 2005, 2006, and 2007, smalls were pooled with mediums, and the large samples from adjacent years were used for the lack of samples in 1996, 1999, and 2001. Sampling coverage may have been poor but length frequency samples appeared relatively constant over time and there was a substantial amount of overlap between market categories which help justify the pooling used in the assessment. Lengths of kept fish from observer data were used to supplement length data of unclassified fish. Kept fish lengths taken from gillnet trips in the observer data were used to characterize the gillnet proportion of the landings (Table C5). In 2002 gillnet landings also shifted from occurring mostly in the first half of the year to a greater proportion coming from the second half. In general there has been an increase in the sampling intensity from the commercial ports. However the decline in landings has made it difficult to get samples from the medium and large market categories in recent years. As in GARM III catch at age and catch at length was estimated using observe kept length measurements by gear supplemented with unclassified port lengths by gear from 1999 to 2010. Characterization of the landings using the observer data produced expanded catch at length distributions similar to the length expansions using the port samples by market category for years which had relatively good port sampling (Figures C6 and C7). Size distributions of the landings have been very stable over the past 10 years (Figure C7).

Discards were estimated for the large mesh trawl (1982-2010), gillnet (1986-2010), and northern shrimp fishery (1982-2010) (Table C6 through C7). The survey method was used in estimating both the discard and proportion discards at length for the large mesh trawl fishery from 1982-1988 (Mayo et al. 1992). Observer discard to landings of all species ratios were applied to corresponding commercial fishery landings to estimate discards in weight from 1989 to 2010 for the large mesh trawl fishery. (Wigley et al. 2008)The Fishery Observer length frequency samples were judged inadequate to characterize the proportion discarded at length from 1989 to 1998 for the large mesh trawl fishery and the length proportion from the survey method was used to characterize the size distribution of discarded fish. Observer discard length sampling increased in 2001 and was used to characterize the large mesh trawl discards from 2001 to 2010 (Table C8). The observer sum discarded to landing of all species ratios were used for estimating gillnet discard rates. Observer sum discarded to days fished ratios were used for the northern shrimp fishery since landing of winter flounder in the shrimp fishery is prohibited. The observer length frequency data for gillnet and the northern shrimp fishery were used to characterize the proportion discarded at length. The sample proportion at length, converted to weight, was used to convert the discard estimate in weight to numbers at length. Data from the small mesh trawl fishery was judged as inadequate to estimate discards over the time series (Tables C7 and C9). Observer coverage has improved in the small mesh fishery over the last ten years. The small mesh discard estimates suggests that the discards are small from this fishery. However the estimate in 2010 did showed an increase. As in the southern New England stock (NEFSC 1999), a 50% mortality rate was applied to all commercial discard data (Howell et al., 1992). Numbers at ages were determined using NEFSC/MDMF spring and NEFSC fall survey age-length keys.

A discard mortality of 15% was assumed for recreational discards (B2 category from MRFSS data), as assumed in Howell et al. (1992). Discard losses peaked in 1982 at 140,000 fish. Discards have since declined to an average of about 8,000 fish from 2000 to 2010 (Table C3, Figure C5). Since 1997, irregular sampling of the recreational fisheries by state fisheries agencies has indicated that the discard is usually of fish below the minimum landing size of 12 inches (30 cm). For 1982-2006, the recreational discard has been assumed to have the same length frequency as the catch in the MDMF survey below the legal size and above an assumed hookable fish size (13 cm). Since 2007 lengths of B2 released catch have been collected by the MRFSS program on party charter vessels which were used to characterize the size of the B2 catch. The recreational discard for 1982-2010 is aged using NEFSC/MDMF spring and NEFSC fall survey age-length keys.

A summary of how the catch at age was constructed can be seen in Table C10. Predicted landings using the same discard method was used as a diagnostic of the discard estimates (Table C11). The predicted landings using the kept to landing of all species ratio are variable but on the same order of magnitude with the dealer landings (Table C1). Decreases in the catch and the catch at age components are shown in Table C12 through C16 and Figures C8 and C9. Mean weights at age and the total catch at age are given in Table C17 and Figure C10. Declines in the mean weights at age were observed for most ages in the catch at age over the last four years.

TOR 2: Present survey data being considered and/or used in the assessment (e.g., regional indices of abundance, recruitment, state and other surveys, age-length data, etc.). Characterize uncertainty in these sources of data.

Mean number per tow indices for the NEFSC and the Massachusetts Division of Marine Fisheries (MDMF) spring and fall time series are presented in Table C18 and Figures C9 through C15. In 2009, the *NOAA SHIP Henry B. Bigelow* replaced the *R/V Albatross IV* as the primary vessel for conducting spring and fall annual bottom trawl surveys for the Northeast Fisheries Science Center (NEFSC). There are many differences in the vessel operation, gear, and towing procedures between the new and old research platforms (NEFSC Vessel Calibration Working Group 2007). For most flatfishes there is evidence for differences in selectivity at length between the two survey vessels. The SDWG used the estimated length based calibration by stock to convert the survey indices in 2009 and 2010 into Albatross equivalent units (Figure C16). Details on the estimation of length based calibration coefficients at length is outlined in a working paper by Miller entitled “Winter Flounder Length-based Survey Calibration”. Both the length based and published peer reviewed aggregate calibration effects can be seen in Figures C11 and C12 (Miller 2011, Miller et al., 2010). The survey length and calibrated lengths can be seen in Figures C17 and C18.

All of the indices generally show a slight decrease in the population in the late 1980s from a high in the early 1980s with low abundance remaining through the early 1990s. All of the indices show signs of increase abundance starting in 1998 and 1999. Since 2001 all indices indicate a decrease in abundance (Figure C15). The MDMF survey catchability is on the order of 60 to 100 fish per tow while NEFSC survey catchability is on the order of 4 to 14 fish per tow. Age data for the MDMF fall survey are not available. The NEFSC fall ages were used to age the MDMF fall index.

Maine and New Hampshire (MENH) have been conducting an inshore bottom trawl survey in the spring since 2001 and in the fall since 2000. These survey indices are relatively flat over the time series with slightly higher abundance in the fall of 2010 (Figure C19). The MENH survey catches relatively few fish over 30 cms (Figures C20 and C21). Age modes for the younger fish are also not clearly seen in the size data. However the increase in the fall of 2010 could be due to an incoming stronger year class. A more defined mode at 9cm can be seen in the fall of 2010 (Figures C21). The working group examined some preliminary age information from the spring MENH index. It was noted that growth from inshore Maine and New Hampshire appears to be slower relative to the MDMF and NEFSC surveys. The MENH indices at age were not included in the models for this assessment due to time constraints and missing age data for some years. However the MENH survey was used in the direct biomass area swept estimate.

Normandeau Associates, Inc. monitored entrainment of winter flounder larvae through the Pilgrim Nuclear power plant since 1975. In general this data suggests a higher abundance of winter flounder larvae since 1997 relative to the 1980s and early 1990s (Figure C22).

An examination of the survey catch per tow at length was conducted to determine the ability of the survey in tracking cohorts. Survey catch per tow at length were plotted with alternating spring and fall surveys over time (Figures C23 through C25). Year classes modes were approximated using growth information. The growth and tracking of cohorts in the younger ages can be seen in the MDMF spring and fall surveys. The younger length modes are more difficult to observe in the NEFSC survey which has a lower catchability for the smaller fish. The raw length frequency data suggests the occurrence of a strong 1998 yearclass evident in both the MDMF and NEFSC surveys. However the detection of this yearclass as it growths above legal size is more difficult to discern (Figure C23 and C24). The strong 1998 yearclass is not estimated in the VPA model. However the tracking of year classes is more difficult to observe in the indices at age (Figures C26 through C28).

Some evidence for a change in the spatial distribution can be seen in the MDMF and NEFSC surveys. There appears to be a shift in abundance for all sizes from shallow water in early 1980s to deeper strata at the end of the time series (Figure C29). Offshore stratum 26 which contains Stellwagon bank also shows increase abundance starting in 1999 while the northern offshore strata off the coast of Maine show no signs of recent increases (Figures C30 and C31). Input from fishermen at the SMAST Fishermen input meeting also reiterated this observation. It is not clear how this shift effects the interpretation of the survey indices. Speculation on a reason for why the survey trends are relatively flat over the time series could be due to a greater proportion of the population residing within the estuaries during the 1980s during the height of the recreational fishery. Fish that reside within the estuaries are not covered by any survey.

TOR 3: Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series (integrating results from TOR-5), and estimate their uncertainty. Include area-swept biomass estimates. Investigate if implied survey gear or catchability estimates are reasonable. Include a historical retrospective analysis to allow a comparison with previous assessment results.

[SAW52 Editor's Note: The SARC-52 peer review panel concluded that no ASAP model run provided a suitable basis for management advice. A swept-area biomass method was accepted instead, and it is described in Appendix C1. The ASAP model and results are included below in this report to document the ASAP modeling runs that the SAW Working Group provided to the SARC for peer review.]

Instantaneous Natural Mortality (M)

The SDWG adopted a change in the instantaneous rate of natural mortality (M) for the winter flounder stocks. The value of M previously used in all assessments was 0.2 for all ages and years, and was based on the ICES 3/Tmax "rule-of-thumb" using observed maximum ages for winter flounder (Tmax) of about 15. The current observed Tmax values for the three stock units are GOM = 15 years, GBK = 18 years, and SNE/MA = 16 years (see Growth and Maturity section, above). The adopted change increases this rate to 0.3 for all stocks, ages and years. Evidence can be found in the literature and current model diagnostics to support the increase.

Literature values of M from tagging studies and life history equations indicate M for winter flounder is likely higher than 0.2. Dickie and McCraken (1955) carried out a tagging study in St. Mary Bay, Nova Scotia, Canada (GOM Stock) and estimated a percentage natural mortality rate to be 30% (M = 0.36). Saila et al. (1965) applied Ricker's equilibrium yield equation to winter flounder from Rhode Island waters (Tmax = 12) and using F values from Berry et al. (1965) calculated M to be 0.36. Poole (1969) analyzed tagging data from New York waters from five different years and estimated values for M of 0.54 (1937), 0.33 (1938), 0.5 (1964), 0.52 (1965), and 0.52 (1966). Finally, an analysis of tagging data from a large scale study along the coast of Massachusetts provided a percentage natural mortality rate of 27%, or M = 0.32 (Howe and Coates 1975). For this assessment, a re-analysis of the Howe and Coates (1975) tagging data was conducted using a contemporary tagging model to estimate natural mortality (Wood WP 15). The tagging model fit to the data was the instantaneous rates formulation of the Brownie et al. (1985) recovery model (Hoenig et al. 1998). This work provided an M of 0.30 with 95% confidence interval from 0.259 to 0.346.

Values derived from life history equations found in the literature also support a higher estimate of M for winter flounder. Three equations were used along with a maximum age (Tmax) of 16 to derive estimates of M equal to 0.28, 0.26, and 0.19 (the equations from Hoenig 1983, Hewitt and Hoenig 2005, and ICES, respectively). A newly proposed method from Gislason et al. (2010), based on SNE/MA stock mean size at age (Ages 1-16) and von Bertalanffy growth parameters, estimated M to be 0.37 (see text table below).

Values of Natural Mortality (M) for winter flounder found in the

literature and derived using life-history equations.

Study	**Method**	**M**
ICES rule-of-thumb	Equation: 3/Tmax	0.19
Hewett and Hoenig 2005	Equation: 4.22/Tmax	0.26
Hoenig 1983	Equation: 1.44-0.982*ln(Tmax)	0.28
Howe and Coates 1975	Analysis of Tagging Data	0.32
Wood 2011 WP15	Re-analysis of Howe and Coates 1975	0.30
Poole 1969	Analysis of Tagging Data from 1938	0.33
Dickie and McCraken 1955	Analysis of Tagging Data	0.36
Saila et al. 1965	Ricker Equil. Yield Equation and Tmax	0.36
Gislason et al. 2010	Equation: Mean size at age and VBG	0.37
Poole 1969	Analysis of Tagging Data from 1964	0.50
Poole 1969	Analysis of Tagging Data from 1965	0.52
Poole 1969	Analysis of Tagging Data from 1966	0.52
Poole 1969	Analysis of Tagging Data from 1937	0.54

Preliminary assessment population model run diagnostics also in general support a higher value for M. Profiles in mean squared residual for ADAPT VPA SNE/MA stock models indicate best fits for M in the range of 0.2 to 0.3. The likelihood profile of initial ASAP SCAA model runs for the SNE/MA stock indicates a best fit for M= 0.6. Model runs from Rademeyer and Butterworth SCAA (ASPM) model (2011) at M equal to 0.2, 0.3, and 0.4 also reveal decreasing negative log-likelihood as M is increased for GOM and SNE/MA stock models (see text table below).

Results of SCAA for the **Gulf of Maine winter flounder** for each combination of 3 levels of natural mortality (*M*=0.2, 0.3 and 0.4, constant throughout the assessment period) and 3 weightings of the survey CAA likelihood (*w*=0.1, 0.3 and 0.5). The runs with w=0.3 and 0.5 have both commercial and survey selectivities flat at older ages, while the runs with w=0.1 have only the commercial selectivity flat. Displayed values are the negative log-likelihoods of each model.

		M	
Weighting	0.2	0.3	0.4
0.1	-123.2	-126.6	-129.1
0.3	-156.9	-177.2	-196.1
0.5	-255.6	-263.2	-280.8

Results of SCAA for the **SNE/MA winter flounder** for 3 levels of natural mortality for Base Case 2. Displayed values are the negative log-likelihoods of each model.

	M		
	0.2	0.3	0.4
-LL	-123.2	-126.6	-129.1

The SDWG also considered other evidence that might justify an increase in M for winter flounder. The NEFSC's food habits database (Smith and Link 2010) was examined to identify the major fish predators of winter flounder. These predators include Atlantic cod, sea raven, monkfish (goosefish), spiny dogfish, winter skate and little skate. A preliminary examination was undertaken to determine the prominence of winter flounder in the diets of these predators, across all seasons, years, size classes of predator, sizes of prey, and geographic locales. The overall frequency of occurrence of winter flounder in the stomachs is not a common or high occurrence (see text table below), always less than 0.15%.

Occurrence of winter flounder in their major fish predators.

	Number of stomachs	Occurrences of winter flounder	% Freq. of occurrence
Spiny dogfish	67,565	27	0.040%
Winter skate	17,708	6	0.034%
Little skate	28,725	6	0.021%
Atlantic cod	20,142	27	0.134%
Sea raven	7,968	10	0.126%
Goosefish	10,742	12	0.112%

Further, the contribution of winter flounder to the diets of these predators species is also notably small (see text table below), usually less than 0.4%.

Contribution of winter flounder to the diet of their major fish predators.

	% Diet composition of winter flounder,	95% CI
Spiny dogfish	0.2049%	0.10678
Winter skate	0.1454%	0.16008
Little skate	0.0124%	0.01618
Atlantic cod	0.3172%	0.24032
Sea raven	0.8831%	0.78407
Goosefish	0.2492%	0.25947

Understandably the temptation exists to evaluate these relatively low contributions of diet with respect to consumptive removals of winter flounder as compared to winter flounder stock abundance and (relatively low) landings, initially using *ad hoc* or proxy methods. Yet just as one would not do so when assessing the status of a stock without a fuller exploration of all the sensitivities, uncertainties and caveats of the appropriate estimators and parameters, the SDWG did not recommend doing so for scoping winter flounder predatory removals at this time. The SDWG also noted that for percentages as low as observed, when allocated to the three winter flounder stocks and explored seasonally or as a time series, there are going to be large numbers of zeroes and attendant uncertainties and variances that would logically offset any potentially high individual predator total population-level consumption rates. Thus, the SDWG does not provide comment as to the merit of exploring or relative magnitude of the issue, but recommends that the topic should be forwarded as an important research recommendation. Other sources of increased natural mortality may come from perceived increases in seal populations along the New England coast, which are known to be predators of winter flounder (Ampela 2009). Population size was estimated at 5600 seals in 1999 (Waring et al. 2007) and a current survey is being conducted to estimate the size of the seal population. However, no time series of seal abundance or consumption of winter flounder is available.

Stock Assessment Models

Abundance indices at age were available from several research surveys: NEFSC spring bottom trawl ages 1-8+, NEFSC fall ages 1-8+ (advanced to tune January 1 abundance of ages 2-8+), Massachusetts spring ages 1-8+, and Massachusetts fall ages 0-8+ (advanced to tune January 1 abundance of ages 1-8+) (Figures C32). The influence of the length based conversion on the indices at age can be seen in Figure C33. The survey mean lengths at age also showed a slight decline at the end of the time series (Figure C34).

There was little change in the female 3 year moving average maturity using MDMF spring survey (Figure C35). A logistic maturity estimate using all years combined (1982-2010) from the spring MDMF survey did not change from the maturity schedule estimated (1982-2007) from GARM III (Figure C36). A histological maturation study described in the working paper by McBride et al 2011 indicated that the MDMF survey macroscopic maturation estimate was appropriate for this stock.

The base and split VPA with assumed natural mortality equal to 0.2 was updated from the GARM III assessment. Differences between the split VPA m=0.2 and m=0.3 can be seen in Figure C37. There was little difference in retrospective pattern between the split model with m=0.2 to the split model m=0.3. All subsequent model runs were done with m=0.3 based on the SDWG conclusion above. As in GARM III the base case VPA run showed a severe pattern in the residuals (Figure C38) and exhibits a severe retrospective pattern in F, recruitment, and a large overestimation of SSB (Figures C39 and C40). Splitting the surveys allows the model to estimate further declines in abundance with higher Fs at the end of the time series. The split survey model is less constrained by the conflicting signals between the large decline in the catch and the survey abundance of the older fish (4+) at the end of the time series. As in GARM III, splitting all of the surveys between 1993 and 1994 did improve the retrospective pattern (Figures C41 and C42). The survey split in the updated assessment appears to have reduced the retrospective bias further then what was observed in the GARM III split VPA model. In addition the update split model estimates for 2007 was similar to the terminal year estimates from the GARM III split VPA which can be seen in the historical retrospective plots in Figures C43 and C44. However other diagnostics still imply major sources for concern surrounding the VPA model formulation for GOM winter flounder. 1) A significant residual pattern in the survey exists for the first half of the model (1982-1993), however the residual pattern seems to have improved for the second half (1994-2010) (Figure C38). 2) Forward and backward diagnostic calculations of the plus group suggest that the plus group estimates are not well determined (Table C19). 3) Area swept Q estimates suggest efficiencies greater than one in both the base and split model runs indicating that the area swept survey population estimate is higher than what is estimated by the model (Figures C45 and C46). 4) The split model results in a large change in the Q estimate. Many of the survey Qs more than tripled in the split VPA run. 5) Biological reasons for a strong dome shape pattern in the Q at age from the surveys is difficult to understand (Figures C45 and C46). However this dome shape concern in the surveys also exists in the forward projecting age structured models.

The SCALE model is a simple forward projecting model that tunes to age data for the younger recruitment ages (age 1, 2, and 3) and length data for the larger adult fish (30+ cm). The SCALE model assumes an overall time invariant growth curve with assumed input variation around the mean lengths at age. The model also assumes flat-topped selectivity in the surveys. The Base SCALE model run possessed a similar retrospective pattern as the VPA. The split SCALE model results were sensitive to the weighting on the recruitment indices. The SDWG did a brief exploration of the SCALE model for this assessment. The SCALE model appeared to possess similar diagnostic issues as observed during GARM III. The estimated selectivity and fishing mortality was sensitive to the assumed input variation on the growth (mean lengths at age). The SDWG concentrated on developing the assessment in ASAP (Age Structured Assessment Program) since there appeared to be greater dynamics present in the indices at age relative to the apparent lack of change in the size structure over time. In addition ASAP allows for the estimation of dome shape selectivity patterns in the surveys.

Preliminary runs were first developed in ASAP similar to the base and split VPA configuration. Indices were input as indices at age. This preliminary runs had a relatively high weight on fitting the catch at age compositions (150 effective sample size). The preliminary runs showed similar results as the VPA with similar diagnostic issues (Figure C47). However, the split ASAP model possessed a severe retrospective pattern (Figure C48). The split in ASAP did not reduce the retrospective pattern as observed with the split VPA model.

Reducing the weight on fitting the catch at age composition (50 effective sample size) in the ASAP base model allows a better fit to the survey indices. Trends in the estimated stock numbers at age can be seen in Figure C49. The estimated biomass over the last decade increases as the weight on the catch at age composition is lowered. This results in further overestimation of the plus group relative to the run with a higher weight (150) on the catch at age composition (Figures C50 and C51). The retrospective pattern with an effective sample size weight of 50 compared to a weight of 150 also showed a reduction in the retrospective pattern (Figure C52 and C53). Similar results were seen with the modeling of Gulf of Maine winter flounder done in an Age-Structured Production Model (ASPM) which is described in Rademeyer and Butterworth MS 2011. The 50 weight model showed a similar dome shaped pattern in Qs as the split VPA (Figure C54).

The SDWG also explored an ASAP model formulation which fit the aggregated survey indices and survey age structure as a multinomial. This formulation does allow for fixing the assumptions on survey selectivity. In general both ASAP formulations produced similar results. The multinomial (ASAP multi run) formation did produce some difference in estimated biomass trends at the start of the model (1980s) and a lower estimate of biomass at the end of the time series. The SDWG did some further refinement to the final multi run through the estimate of a separate selectivity block from 1998 to 2010. This did result in a slight shift in the selectivity to older fish for the second time block as observed in the catch at age. Fits to catch at age composition, estimated survey selectivity, fits to the aggregate survey indices, predicted stock numbers at age, and the retrospective pattern can be seen in Figures C55 to C60. The difficulties in estimating population scale can be seen when comparing the results from different models (VPA and ASAP) and for models with different weighting on the data sources (Figure C61).

The combined survey area swept 30+ biomass estimates are described in Appendix C1. The fall survey biomass estimates were judge more appropriate since a greater proportion of the population should be within the survey area during the fall because the fish are not spawning within the estuaries at that time. The area swept 30+ biomass for the fall between 2009 and 2010 ranged from 6,300 mt to 7,600 mt assuming a gear efficiency of 60 percent (q=0.6). This survey based biomass estimate was used to inform the weighting on the catch at age composition used in the model. Therefore the 30+ biomass estimate at the end of the time series was important for judging the feasibility of the model results. For example the ASAP which used dome shape fishery selectivity had desirable diagnostic properties but the biomass estimates were unfeasibly high at the end of the time series (over 20,000 mt). The 30+ cm biomass estimate from the survey estimate is comparable to the 4+ biomass, exploitable biomass, and the SSB in 2009 and 2010 from the SDWG multi ASAP run (Figures C62 and C63).

Age Structured Assessment Program (ASAP) Description

ASAP (Age Structured Assessment Program v2.0.20, Legault and Restrepo 1998) and the technical manual can be obtained from the NOAA Fisheries Toolbox (http://nft.nefsc.noaa.gov/). ASAP is an age-structured model that uses forward computations assuming separability of fishing mortality into year and age components to estimate population sizes given observed catches, catch-at-age, and indices of abundance. Discards can be treated explicitly. The separability assumption is partially relaxed by allowing for fleet-specific computations and by allowing the selectivity at age to change in blocks of years. Weights are input for different components of the objective function which allows for configurations ranging from relatively simple age-structured production models to fully parameterized statistical catch at age models.

The objective function is the sum of the negative log-likelihood of the fit to various model components. In the SDWG preferred ASAP multi run the catch at age and survey age composition are modeled assuming a multinomial distribution, while most other model components are assumed to have lognormal error. Specifically, lognormal error is assumed for: total catch in weight by fleet, survey indices, stock recruit relationship, and annual deviations in fishing mortality. Recruitment deviations are also assumed to follow a lognormal distribution, with annual deviations estimated as a bounded vector to force them to sum to zero (this centers the predictions on the expected stock recruit relationship).

ASAP Model Inputs and Formulation

The ASAP model formulation used a composite catch by a directed fleet starting in 1982. Commercial landings do exist prior to 1982. However recreational landings are unknown prior to 1981. All models included the NEFSC spring and fall as well as the Massachusetts state surveys for both the spring and fall. Minimum swept area abundances and an assumed CV of 0.4, as well as age composition for each survey were used in the model. The working group focused initial scrutiny on models that treated the survey indices by age, similar to a VPA model formulation but due to difficulties to reconcile model diagnostics, the multinomial formulation was preferred by the working group. The preferred ASAP multi model used a plus group at age 7. Exploratory runs examined model sensitivity to estimating a stock recruit function versus estimating an average recruitment with annual deviations; estimating age-specific selectivity for the surveys versus forcing the survey to have a flat-topped selectivity; "breaking" the survey time series into two separate series or maintaining a continuous time series; and adding or removing selectivity "blocks" to the directed and bycatch fleets. In considering these various model iterations, diagnostics were examined to determine if the fit improved. Specifically, the pattern of residuals in age composition for catch and indices, residuals in the fit to total catch and annual index values, components of the objective function in addition to total objective function and number of estimated parameters, as well as the "feasibility " of the estimated selectivity patterns were examined. With regard to the last criterion ("feasibility" of estimated selectivity), the models tended towards solutions with sharply domed selectivities for both the directed fleet and the surveys. As there was nothing biological to suggest that fish at ages 5 and beyond would have very low catchability (i.e., no known behavioral aspects, no strong swimming capabilities), nothing gear related that would suggest lower catchability (no outswimming otter trawls, no other known gear interactions), and no known market conditions that would favor smaller fish. The SDWG found it hard to reconcile selectivities of 0.10 on the 7+ group.

Model formulations for both the indices at age and the multinomial model were examined. Although the objective function values were not directly comparable between these two model treatments, owing to differences in the underlying data, residual diagnostics, overall fits, and retrospective patterns were compared. The working group agreed to the following preferred multi configuration: A model that did not split the survey indices, two selectivity blocks for the directed fleet (the break occurred between 1997 and 1998), forced with a selectivity = 1 for ages 4 and older. With all models considered, there was a strong correlation between the selectivity estimated for the directed fleet and the selectivity of the surveys. Forcing a flattop for the survey indices caused the selectivity estimates for the directed fleet to be also flattopped. Similarly, allowing a dome in the survey led to dome selectivity in the directed fishery. For this reason, a flattop was assumed for the directed fleet fishery. For this selectivity pattern, the age composition residuals showed some patterning, particularly in the plus age category and the overall index as well as the total catch showed some time trends in the fit to the residuals. In contrast, when a dome selectivity is estimated in the fishery, there was an improvement in both the residual age composition and residual fit the overall index and total catch. However, the estimates of spawning stock biomass and recruitment were unreasonably high due to cryptic biomass that was generated from the dome selectivity pattern. Although the flattop configuration did not provide the best diagnostics, the estimates of spawning stock biomass and recruitment were within reason. This is a fairly consistent trade-off seen in many of the model diagnostics, wherein improvements in the fit to the catch at age, including the total data (catch or total index values) results in a different perception of the stock. Thus, selecting the 'best' model depended to some extent on the amount of confidence that one had in the age composition data as well as the total catch and the indices. Complete diagnostic output plots can be found in the Appendix C2 ("Multi models diagnostics_2_Block_Fishery_Selectivity").

Preferred ASAP Multi model Retrospective Pattern

A retrospective analysis on the ASAP multi model using a seven year peel was conducted to examine the stability of the model estimate for fishing mortality, recruitment and spawning stock biomass (Figures C59 and C60). Due to the change in selectivity block beginning in 1998, it was difficult to interpret the earliest peels because there was an imbalance in the number of parameters being estimated versus number of years with additional data. However, it was noted that the model that estimated a dome in the directed fleet had the lowest retrospective while the preferred multi model exhibited higher retrospective averages.

Preferred ASAP Multi model Sensitivity Analyses

For completeness, sensitivity to the model decisions adopted in the base model are summarized in Table C20. Seven additional runs were explored including assuming survey flattop selectivity, lowering or increasing the age to fix survey selectivity, allowing a dome in the fishery and removing time blocks in the fishery selectivity. Due to convergence problems in some of the sensitivity runs, only four of the seven sensitivity runs were reported. Only one of the four runs reported assumed no time blocks in the directed fishery selectivity. The motivation for introducing selectivity blocks, and the year that they were introduced, was an attempt to account for changes in the fishery composition and pertinent regulations (mesh size and minimum sizes changes). While this model offered similar diagnostics as in the ASAP multi run, the retrospective estimates were improved for spawning stock biomass, recruitment and Fishing mortality. The overall objective function for the single block directed fishery was 3480 while for the base model, it was 3453. Thus, the multi run which estimated an additional block of selectivity improved the objective function by 27 points at the cost adding four additional parameters to the model.

The remaining three models were based on the two block selectivity in the fishery. Lowering the age to fix the survey selectivity suggested improvement in the likelihood components of the model. However, the model had problem converging, possibly due to parameter boundary issue as hessian was obtained for the model. Assuming flattop in the survey did not improve the overall objective likelihood function neither did it provide improved diagnostic in comparison to the ASAP multi run. Additionally, survey catchability for the Massachusetts state survey was greater than one and the retrospective estimates deteriorate substantially.

Preferred ASAP multi Model Results

Fishing mortality on ages 3+ varied between 0.359and 0.648 from 1982 to 1989 then decreased consistently since 1990 from 0.586 to 0.102 in 1999. Fishing mortality Varied slightly between 0.138 and 0.058 from 2000 to 2009. The fishing mortality rate in 2010 is estimated to be 0.032 (80% confidence interval 0.026 – 0.038; Figures C63 and C64).

Recruitment has been relatively stable throughout the time series. Mean recruitment was around 8.1million for age1 recruits. Several abundant year classes were produced in 1982-1983, 1985, 2004,-2007 ranging from 10 million to 11.9 million. Recruitment in 2010 is estimated to be 4.7 million, lowest in the time series (80% Confidence interval 3.2 million – 6.2million).

Spawning stock biomass declined substantially early in the time series from 12,506 metric tons in 1982 to 1,487 metric tons in 1993, lowest in the time series. Thereafter, SSB has steadily increased from 1,664 metric tons in 1994 to 5,817 metric tons in 2009. Spawning stock biomass in 2010 is estimated to be 5,803 metric tons (80% confidence interval 4,901 – 6,705 metric tons; Figures C63 and C64).

SDWG Stock Assessment Model Discussion and Conclusions

The population models have difficulty with the conflicting data trends within the assessment, specifically the large decrease in the catch over the time series with very little change in the indices or age structure in both the catch and surveys. These conflicting signals were identified in GARM III and results in a severe retrospective pattern in the modeling. Splitting of the survey indices did help reduce the retrospective bias in the models. However the magnitude of the change in q estimated from the split that was required for the model to fit the lack of older fish in the catch at age was no longer believable. Area swept q estimates (2-3 second half) which exceeded 1 suggested that model estimates of biomass was far lower then what was observed in the surveys. At GARM III stock status determination changed from not overfished and not overfishing to overfished and overfishing with the split. Examination of an alternative forward projecting model (SCALE) that tunes to length data produced similar results and had similar diagnostic issues as the VPA. Status determination from the SCALE model was also sensitive the weighing of different data components. The lack of fit to the survey indices in the GARM III VPA resulted in high uncertainty in the status determination which led to rejection of the models.

Conflicting trends in the data still exist in this assessment. However there are several changes that contribute to change in the estimated population trends and status determination relative to the GARM III models. 1) The change in assumed natural mortality from 0.2 to 0.3. 2) Trends at the end of the assessment during the GARM III where difficult to interpret due to the declining catch with declines in the survey index for older fish (4+) at the end of the time series in 2007. This assessment added three more years (2008-2010) to the GARM assessment. 3) There have been increases in the indices at age for the older fish (5,6 7+) since the GARM assessment. 4) The biggest change that contributed to the change in population trends was the switch in the modeling of the stock to ASAP which allowed errors in the fit to the catch at age and a better fit to the surveys indices without the split.

Population scale is poorly determined within the modeling due to the conflicting data trends. The scaling of the population estimates was sensitive to the weight imposed on the catch at age compositions. The conflicting trends in the data produce a bifurcation in the model results. This was observed in both the ASAP and ASPM modeling work from Rademeyer and Butterworth MS 2011. Forward projections models that are forced to fit the catch at age cannot fit the survey indices and result in similar trends as seen in the VPA. Tension within the model is lowered, retrospective bias is reduced, and population estimates are scaled higher with larger increases at the end of the time series as the fit on the catch at age composition in ASAP and ASPM models is relaxed.   Preferred ASAP and ASPM models assumed a flat-topped selectivity pattern. This results in an overestimation of fish in the plus group as the fit to the catch at age composition is lowered. Allowing both models to fit a dome shape selectivity pattern further releases the tension within the model and allows the estimation of the strong dome shaped pattern with unrealistically high biomass estimates at the end of the time series.

The SDWG developed a table outlining the reasons why the ASAP multi model was the preferred model in this assessment (Table C21). The split VPA lack of fit to the overall survey indices with estimates on biomass far below the minimum area swept numbers made it difficult for the SDWG to accept this model formulation. The ASAP model formulation did not require a split survey configuration to adjust for the retrospective pattern. The combined survey 30+ biomass area swept estimate was used to inform the optimal weighting for the preferred model formulation. The resulting final model weighting formulation considered both the tradeoff between retrospective bias and feasible biomass estimates at the end of the time series. A retrospective pattern did exist in the preferred ASAP multi run but the SDWG noted that the last two years of the model appeared to be consistently estimated. The within model uncertainty will not capture the uncertainty in this assessment considering how sensitivity the results are to the model formulation and weighting.

The SARC concluded that the assessment model were too unreliable as a basis for management. The accepted assessment of GOM winter flounder stock is based on an empirical swept-area model utilizing data from the 2010 NEFSC fall survey, the MADMF fall survey, and the Maine-New Hampshire fall inshore surveys which is summarized in apppendex C1. Using an efficiency value of 0.6 the estimated stock biomass in 2010 of fish greater than 30 cm was 6,341 mt (80% CI 4,230 - 8,800 mt).

TOR 4: Perform a sensitivity analysis which examines the impact of allocation of catch to stock areas on model performance (in TOR-3).

The SDWG interpretation of TOR4 is that the variance of the commercial landings due to the 1995 and later area-allocation scheme should be used as the basis for the magnitude of landings that might be lost or gained from the stock-specific assessments, and then perform an exercise to run the assessment model with those potential biases and report the results. Additional work was done to estimate the error in the commercial landings due to misreporting of commercial landings to statistical area at allocation level A, the initial reporting level in mandatory Vessel Trip Reports (VTRs; Palmer and Wigley MS 2011). Vessel monitoring system (VMS) positional data from northeast United States fisheries for 2004-2008 were used to validate the statistical area fished and stock allocation of commercial landings derived from the VTRs. The accuracy of the VMS method relative to the VTRs was assessed using haul locations and catch data recorded by at-sea observers. This work was performed for several New England groundfish species. The perceived under-reporting of statistical areas in the VTR data led to minor (< 5%) differences in the overall species allocations; only nine stocks in the five year time-series exhibited differences in stock allocations exceeding 2.0% (2004: northern and southern silver hake, ± 3.0%; 2006: northern and southern windowpane flounder, ± 4.7%; 2007: Georges Bank winter flounder, 2.4%; 2008: Georges Bank winter flounder, 2.4%, Southern New England/Mid-Atlantic winter flounder, -3.2%, and northern and southern windowpane flounder, ± 3.4%). Given the magnitude of these errors, the SDWG elected to run the final GOM winter flounder ASAP model, with an additional 5% PSE in commercial landings added to the estimated PSE over the 1995-2010 time series.

For the GOM stock the total catch consists of 4 components. The commercial landings have a calculated Proportional Standard Error (PSE; due to the commercial landings area-allocation procedure; available for 1995 and later years, with the mean of those years substituted for 1982-1994) ranging from 5.3% to about 6.5%; the commercial discard (trawl and gillnet) PSEs range from 16-177% (available for 1994-2010, mean of those years substituted for 1982-1993); and the recreational landings PSEs range from 17-50%. Because the PSEs for the commercial landings are low, and the commercial landings account for about two-thirds of the total catch, the total catch weighted-average annual PSEs range from 7-30%, and averages 11.7% (unweighted) for the 1981-2010 time series.

The catch in the final assessment model was increased and decreased by the annually varying PSE and models re-run to provide an additional measure of uncertainty of assessment estimates. For the final ASAP multi model, the fishing mortality estimate in 2010 did not change greatly (0.01 to 0.034). The 2010 SSB range was 4,700 to 6,900 mt, was similar to the MCMC estimate of uncertainty (Figures C63 and C65).

TOR 5: Examine the effects of incorporating environmental factors in models of population dynamics (e.g., spring water temperatures in an environmentally-explicit stock recruitment function).

This TOR is addressed in a separate working paper from Hare MS 2011 entitled "Development of environmentally-explicit stock-recruitment models for three stocks of winter flounder (Pseudopleuronectes americanus) along the northeast coast of the United States**".**

To develop environmentally-explicit stock recruitment relationships, three specific types of data are required: spawning stock biomass, recruitment, and environmental data. Spawning stock biomass and recruitment data from the final 2011 SAW 52 assessment models were used in the analysis. For the GOM stock, recruitment (lagged by 1 year) and spawning stock biomass pairs were used from the ASAP multi model. Two general types of temperature data were used: air temperatures and coastal water temperature. In addition to temperature, four large-scale forcing indices were included in the analyses. The North Atlantic Oscillation (NAO) is the dominant mode of winter climate variability in the North Atlantic region and has been related to numerous physical and biological variables across the North Atlantic (Ottersen et al. 2001, Visbeck et al. 2003). The Atlantic Multidecadal Oscillation (AMO) is a natural mode of climate variability and represents a detrended multi-decadal pattern of sea surface temperatures across the North Atlantic with a period of 60-80 years (Kerr 2005). Finally, the Gulf Stream index is a measure of the northern extent of the Gulf Stream south of the northeast U.S. shelf ecosystem. The Gulf Stream position is related to the larger basin-wide circulation, which in turn is related to NAO and AMO. Two Gulf Stream indices are used here (Joyce and Zhang 2010, Taylor and Stephens 1998).

In summary, for the Gulf of Maine stock, increased winter air temperatures are related to lower recruitment, but the strength of this environmental forcing is less than for the Southern New England stock. This result makes sense in the context of the distribution of winter flounder; the southern stock is most affected by warmer temperatures.

One use of the environmentally-explicit models is to develop short-term and long-term forecasting models. Based on the this work, there is no trend in winter temperature over the past 30 years and thus short-term forecasts can be developed using the environmentally-explicit models assuming winter temperatures to be at their mean state. It may also be useful to develop short-term forecasts under warm temperatures and short temperatures to provide managers with a tangible understanding of the effect of temperature on the stocks. The environmentally-explicit models could also be used to develop longer-term forecasts following the approach of Hare et al. (2010). These forecasts would provide an assessment of the sustainability of the winter flounder fishery on the 30-100 time scale.

Work is underway within the SDWG to incorporate environmentally-explicit stock-recruitment models into the NFT standard software used to fit stock-recruitment models and to perform projections of stock and fishery catch. However, this work has not been developed sufficiently to be made available for peer-review at this time (see new Research Recommendation 10).

TOR 6: State the existing stock status definitions for "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; point estimates or proxies for BMSY, BTHRESHOLD, and FMSY) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

The 2008 GARM III assessment was not accepted and the overfished and overfishing status of the GOM winter flounder stock is currently unknown. However GARM III stated that it is highly likely that biomass is below BMSY, and that there is a substantial probability that it is below the ½ BMSY threshold. A rebuilding schedule was not developed for this stock since GARM III stock status was considered unknown and the GARM I and II assessments did not considered the stock overfished.

The estimated biological reference points are summarized in table C22. The split VPA estimated higher percent maximum spawning potential (MSP) proxies relative to the ASAP model because the VPA estimated selectivity was shifted to older fish (Figure C66). The preferred SDWG ASAP multi run estimated a F40 FMSY proxy at 0.34 using the 2006-2010 average mean weights and selectivity as input to the YPR analysis (Table C23; Figure C67). The F40 SSBmsy was estimated from a long term projection (100 years) using the CDF of recruitment from the entire model time series (1982-2010) and the estimated YPR F40. The SSBmsy using the FMSY = F40 proxy was estimated at 3,287 mt with a SSBmsy threshold estimate of 1,644 mt and a MSY equal to 1,080 mt for the ASAP multi run. Stock recruit relationships from the split VPA and ASAP multi run can be seen in figures C68 and C69. The split in the VPA results in a trend in the estimated recruitment which produces a lower steepness and a stronger relationship in the stock recruit curve. Performing a likelihood profile on steepness and a MCMC on the stock recruit model suggests that the steepness, SSBmsy and Fmsy was not well determined from the ASAP multi run (Table C24; Figure C70). The SDWG Beverton Holt stock recruitment Fmsy using the Pleuronectids steepness prior from Myers et al. (1999; 0.8 mean and CV = 0.09) was estimated at 0.57. The stock recruit SSBmsy was estimated at 2,167, SSBmsy threshold = 1,084 mt, and MSY = 1,152. The MSY estimate did not vary greatly with SSBmsy from the MCMC in the stock recruitment analysis (Figure C71). The SDWG expressed concern with the stock recruitment estimate of SSBmsy being estimated in the lower end of the range of past SSB observations.

The SDWG developed a unified response to TOR6, taking into consideration the assessment results for all three stocks. The fishing mortality and biomass Biological Reference Points (BRPs) discussed below are from the Final models accepted for the stocks. As defined in the Magnuson Act, 'overfishing' means "a rate or level of fishing mortality that jeopardizes the capacity of a fishery to produce the maximum sustainable yield on a continuing basis" (i.e., FMSY). The guidelines allow for the projected catch associated with the overfishing limit (OFL) to be based on FMSY proxies. Many proxies are used to define overfishing in situations when FMSY is not well determined. The SDWG interpreted these guidelines to mean that best practice is to use a FMSY estimate instead of a proxy when FMSY can be reliably estimated. The SDWG estimated FSMY for the winter flounder stocks as well as proxies in the form of

F40%. The SDWG developed consensus on some aspects of the FMSY estimates (relative magnitude across stocks), but also had some disagreement about the reliability of FMSY estimates (related to the perceived reliability of the respective assessments). The SDWG could not come to consensus on the preferred MSY reference points for the three winter flounder stocks. Updated estimates of F40% were provided as the existing overfishing definitions and as alternatives to FMSY and SSBMSY estimates. Estimates of F40% and SSB40% were provided as potential overfishing definitions based on the precedence offered by GARM-III (NEFSC 2008), instead of other potential %MSP alternatives.

Appropriateness of FMSY Estimates

The SDWG estimates of FMSY utilize data and prior information in a statistical framework. Estimation of the steepness parameters (*h*) in the stock-recruitment relationships used the available stock-recruitment estimates and a prior distribution of *h* from other Pleuronectid flatfishes (Myers et al. 1999), as was used in previous assessments of SNE/MA winter flounder (NEFSC 2002).

Steepness was estimated to be:

- 0.84 for Gulf of Maine winter flounder
- 0.85 for Georges Bank winter flounder
- 0.64 for SNE/MA winter flounder

The SDWG estimates of *h* for winter flounder stocks are realistic. They are compatible with both the estimates of *h* for Pleuronectids that were used as priors, and with the distribution of all of the estimates in Myers et al. (1999). Uncertainty in FMSY is estimable based on stock-recruitment relationships, but not all sources of uncertainty are included in the SDWG evaluation (e.g., uncertainty in assumed natural mortality, precision and accuracy of stock-recruit estimates are not considered).

Concerns about the reliability of the estimates FMSY

There are aspects of using a prior for steepness for these stocks that are problematic. If no prior is applied, two of the three resulting stock-recruit relationships are not theoretically feasible (e.g., the linear increase in SNE/MA recruitment as a function of spawning stock size; the constant recruitment even at low spawning stock size for GBK winter flounder). There are several concerns with the prior on *h* from Myers et al. (1999) meta-analysis for Pleurinectid flatfishes. The prior is not well understood, because the original data was not available at the SDWG. Many of the stocks used to form the prior have $M < 0.2$. The appropriateness of this prior for the U.S. winter flounder stocks, with assumed $M = 0.3$, is therefore unknown. The number of Pleuronectid stocks in the Myers et al. (1999) study is limited (n=14), and there were no winter flounder stocks included. Derivation of the precision estimate of *h* (0.09; NEFSC 2002) is not clearly documented. The assumed normal error structure for the prior may not be appropriate for a parameter bounded by 0.2 and 1. Myers et al. (1999) stated that "the family-level estimates (shown in boldface) should be used with caution." FMSY estimates depend on both mean and precision of steepness, but the SDWG did not have information on how well the Myers et al. (1999) values were estimated.

The precision of steepness (*h*) estimates show a moderate range of possible values and an associated moderate range in estimates of FMSY(see text table below):

Estimates of steepness (h), FMSY and %MSP with 80% confidence intervals and CVs.

Stock	h	CV	10%	90%	FMSY	CV	10%	90%	%MSP	10%	90%
GOM	0.84	0.08	0.75	0.92	0.565	0.19	0.43	0.77	28	34	21
GBK	0.85	0.08	0.75	0.94	0.500	0.22	0.39	0.69	29	35	22
SNE/MA	0.64	0.08	0.57	0.76	0.310	0.07	0.27	0.43	42	46	32

The implied maximum lifetime reproductive rate [4*h*/(1-*h*)] is quite variable among the stock (*h*=0.64 implies ahat=7.1 while *h*=0.84 implies ahat=21.0), where ahat represents the number of spawners produced by each spawner over its lifetime at very low spawner abundance (i.e., assuming absolutely no density dependence). With similar growth, maturity and natural mortality rates, it is not clear why the implied reproductive rates are so different.

The %MSP associated with the range of FMSYestimates suggests that F40% is compatible with FMSY for SNE/MA winter flounder, but those ranges suggest that F40% is not compatible with FMSY for the GOM and GBK stocks. The %MSP associated with FMSY estimates range from 28% to 42%, but it is again unclear why the %MSP values are up to 50% different for stocks with similar biology and fishery characteristic, when only the stock-recruitment steepness differs.

The SDWG had several concerns about the use of F40% as an overfishing definition. F%MSP ignores any information from stock and recruitment estimates, and therefore may be inconsistent with FMSY estimates that use such information. The performance of F40% for achieving MSY has not been evaluated specifically for winter flounder stocks. The SDWG recognized the logical difference between "data-based" inferences involved in estimates of FMSY vs. “hypothesis-based” expectations of inter-stock similarities, based on analogy to justify F40%.

In summary, from a comparative approach to MSY reference points, F40% is similar for all three stocks. The estimate of FMSY for GOM winter flounder is similar to that for the GBK stock but twice that for the SNE/MA stock. This two-fold range in FMSY among the three stocks is due to the differing patterns in the estimated stock-recruitment data (see text table below). The SNE/MA stock has a low steepness estimate that is driven by estimates of strong recruitment and high spawning stock size from the 1980s. Unlike the situation for SNE/MA winter flounder, for GOM and GBK winter flounder there is no pattern in the stock-recruitment estimates that supports inferences of lower steepness. The influence of environmental conditions that limit recruitment success (e.g., warmer temperatures and subsequent larval predation effects) is a possible explanation of the lower steepness of the SNE/MA stock (and subsequently lower FMSY). The SDWG noted that this explanation assumes no local and complete adaptation to environmental conditions among the stocks.

Stock	F_{MSY}	h	SSB_{MSY}	SSB_0	SSB_0/SSB_{MSY}	MSY	F_{40}	SSB_{40}	MSY_{40}
GOM	0.565	0.84	2,167	8,887	4.10	1,152	0.340	3,287	1,080
GBK	0.500	0.85	8,260	31,478	3.81	4,200	0.320	11,300	3,200
SNE/MA	0.310	0.64	33,820	92,657	2.74	9,763	0.327	29,045	8,903

Implications of Reference Point Decisions

Despite the uncertainty in reference point estimation for SNE/MA Atlantic winter flounder, the determination of stock status and rebuilding conclusions are robust. All candidate reference points lead to a conclusion that the stock cannot rebuild to Bmsy by 2014, even at F=0.

Major uncertainty persists in the GOM winter flounder stock assessment, and estimates of current biomass are much greater than all candidate estimates of BMSY or BMSY proxies. However, the relatively low estimates of F and conclusion that overfishing is not occurring are consistent with recent regulations and restrictions on catch. The estimate of SSBMSY corresponding to h=0.84 for GOM winter flounder is close to the lower end of the range of past SSB estimates, in contrast to the situation for GBK winter flounder, where it is close to the middle of this range. The minimum observed GOM SSB was 1487 mt, and the 80% confidence interval of SSB_{MSY} is 1640 to 2700 mt. Although the 80% confidence intervals for h for each of these two stocks are similar, this feature of the GOM estimates renders them less reliable than those for the GBK stock. While there were disagreements within the SDWG on the BRPs to use as the overfishing definition, the SDWG reached consensus that the current model and associated reference points for Gulf of Maine winter flounder were acceptable and the best that could be determined at this time.

SARC 52 did not accept the SDWG model and the overfished status remains as unknown since biomass based reference points could not be estimated. The SARC accepted a proxy value of the overfishing threshold which was derived from a length-based yield per recruit analysis that assumes all fish above 30 cm are fully recruited to the fishery and that natural mortality is 0.3. Using $F_{40\%}$ (0.31) as a proxy for Fmsy, the threshold exploitation rate is 0.23 and 75%$F_{40\%}$ exploitation was 0.17 with M=0.3. The reference points were converted to exploitation rates to be consistent with the swept area biomass approach (Appendix C1).

TOR 7: Evaluate stock status (overfished and overfishing) with respect to the "new" BRPs (from TOR 6), and with respect to the existing BRPs (from a previous accepted peer review) whose values have been updated.

BRPs for GOM winter flounder from the GARM-III assessment in 2008 (NEFSC CRD08-15) were based on F40%, a proxy for FMSY. SSBMSY and MSY were estimated with the AGEPRO projection model, including the model's CDF of age-1 recruitment and the estimate of F40%. Although BRP's were estimated in GARM-III (F40% = 0.283, SSBMSY = 3,792 mt, and MSY = 917 mt), the GARM-III Review Panel concluded that the assessment did not give "a clear picture of the status of the resource" and that "the proposed analysis could not be used to provide management advice nor stock projections". Therefore, the 2008 assessment was not accepted and the overfished and overfishing status of the GOM winter flounder stock is currently unknown.

Stock status evaluation was consistent regardless of the model formulation (VPA and ASAP) which is summarized in Table C22. Both the split VPA model and the SDWG preferred ASAP multi model indicate that the stock is not overfished and overfishing is not occurring. However spawning stock biomass relative to the SSBmsy varied widely between the VPA and preferred ASAP multi model. SSB in 2010 to SSBmsy ratios varied from the stock recruit Split VPA estimate of 0.52 to the stock recruit estimate of 3.09 from the ASAP multi with no prior on steepness. All models show that fishing mortality in 2010 were well below their respective Fmsy reference points. Fishing mortality in 2010 to Fmsy ratios varied from the stock recruitment split VPA ratio estimate of 0.47 to the stock recruitment estimated ratio of 0.05 from the ASAP multi run with no prior on steepness. The SDWG ASAP multi run using the Fmsy = F40 proxy estimated the SSB2010/SSBmsy ratio at 1.77 and the F2010/F40 at 0.09. The stock recruitment priors did lower the estimated steepness which lowered the SSB2010/SSBmsy ratio to 2.74 and increased the F2010/Fmsy ratio to 0.06.

All GOM winter flounder models have diagnostic issues due to the conflicting signals in the data. The SDWG preferred the ASAP multi model as the best fit to all data sources including considerations for reasonable estimates of biomass in 2009 and 2010 in comparisons to the survey area swept biomass estimates. However the SDWG questioned the feasibility of the estimated SSB relative to the SSBmsy reference points for both the F40 proxy and the stock recruit estimates (1.77 to 2.68). In general the trends and biomass estimated by the model seem appropriate. Surveys and anecdotal feedback from fishermen suggest a shift in the population to deeper water which can help explain the lack of catch in the recreational fishery. However questions remain with the lack of higher catches as the stock rebuilds during the late 1990s and early 2000s when effort in the groundfish fishery was high. In addition, there is little evidence of a change in the size structure or stock range expansion to waters off the coast of Maine which traditionally had higher catches. Considerable uncertainty remains with regards to the comparison of the 2010 SSB relative to the SSBmsy biological reference points.

The SARC concluded that the population models are too uncertain as a based from stock status determination. The overfished status remains as unknown since an analytical model was not accepted and a biomass reference point could not be estimated. The SARC concluded that in 2010 overfishing was not occurring for the stock. A proxy value of the overfishing threshold was derived from a length-based yield per recruit analysis that assumes all fish above 30 cm are fully recruited to the fishery and that natural mortality is 0.3. Using F40% (0.31) as a proxy for Fmsy, the threshold exploitation rate is 0.23. Exploitation rate in 2010 was estimated at 0.03 (80% CI 0.02 - 0.05) which was based on the ratio of 2010 catch (195 mt) to survey swept area estimate of biomass for winter flounder exceeding 30 cm in length (6,341 mt).

TOR 8: Develop and apply analytical approaches and data that can be used for conducting single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs) under a set of alternative harvest scenarios. If the stock needs to be rebuilt, take that into account in these projections.

a. Provide numerical short-term projections (3-5 yrs, or through the end of the rebuilding period, as appropriate). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions about the most important uncertainties in the assessment (e.g., terminal year abundance, variability in recruitment).

b. Take into consideration uncertainties in the assessment and the species biology to describe this stock's vulnerability (see "Appendix to the SAW TORs") to becoming or remaining overfished, and how this could affect the choice of ABC.

c. Develop plausible hypotheses (e.g., mixing among the three stocks) which might explain any conflicting trends in the data and undertake scenario analyses to evaluate the consequences of these alternate hypotheses on ABC determination.

A. Ten year AGEPRO projections assumed that the ACL of 230 mt will be taken in 2011. Projections were done using 1000 bootstrap iterations from the split VPA and 1000 mcmc iterations from the preferred ASAP multi run. Plots with 80 confidence intervals are shown for SSB, catch, and fishing mortality for the split VPA at the Fmsy proxy F40 = 0.43 and 75% of the F40 proxy = 0.32 (Figures C72 and C73). Projections for the ASAP multi model were also run assuming the F40 proxy = 0.34 and 75% of the F40 = 0.26 (Figures C74 and C75). Short term projections using the stock recruit reference point with the prior on steepness for the ASAP multi run were also done at Fmsy = 0.57 and 75%Fmsy = 0.42 (Figures C76 and C77). All projections show relativity high catch in 2012 compared to model time series of catches. The VPA SSB increases towards SSBmsy after low estimates of SSB in 2013 and 2014. The low SSB estimate in 2013 and 2014 is due to the low recruitment estimated in 2009 and 2010 which was influenced by the length based survey conversion. Therefore substantial uncertainty exists with the estimated recruitment in 2009 and 2010. The ASAP multi short term projections result in fishing of the SSB down to SSBmsy. The estimated catch in 2012 shows a large increase relative to the assumed catch in 2011 of 230 mt for both the split VPA and ASAP formulations. The ASAP multi run estimated 2012 catch varies from 1,700 mt from the 75% F40 projection to the stock recruit Fmsy projection estimate of 3,080 mt. However catch declines quickly after 2012 as the stock approaches SSBmsy.

Consideration in the projections could be given to the overestimation of the plus group in the ASAP model. For example a plus group residual adjustment within AGEPRO can be approximated using an assumed plus group discard proportion (Table C25). The effect of the plus group adjustment can be seen in table C25.

B. The Working Group accounted for vulnerability, productivity and susceptibility using conventional MSY reference points, and evaluated uncertainty using model estimates of precision and qualification of other uncertainties. Age-based analytical stock assessment models and associated MSY reference point evaluations provide a relatively comprehensive and synthetic evaluation of vulnerability that is entirely consistent with stock status determination and projection. Vulnerability and susceptibility were accounted for in both aspects of status determination (estimation of F and F_{MSY}) and projections as the magnitude of fishing mortality and recent selectivity at age. All components of productivity (reproduction, individual growth, and survival) were also explicitly accounted for in stock status determination and projections. Reproduction was monitored as age-1 recruitment, and projected as a function of SSB (the product of abundance, weight and maturity at age). Individual growth was monitored as empirical size at age, and projected as recent mean size at age. Survival was accounted for based on model estimates of fishing mortality and selectivity as well as assumed natural mortality, which was informed by tagging analysis. Uncertainties that were not accounted for by assessment and reference point models were evaluated using model diagnostics. Standard model diagnostics (e.g., residual analyses, retrospective analyses) were used for model validation. Retrospective inconsistencies that were outside the bounds of model precision estimates were addressed through selection of alternative models.

Vulnerabilities that were not accounted for from assessment and reference point models were evaluated using exploratory modeling, habitat observations and testing the influence of environmental factors on recruitment dynamics. All three winter flounder stocks are harvested in mixed-stock fisheries, but bycatch and discards are monitored and managed through Annual Catch Limits with Accountability Measures for exceeding those limits.

Additional considerations of vulnerability and productivity are the implications of shifts in distribution, recruitment dynamics and increased natural mortality. Nye et al. (2009) found an annual increase in mean depth of the winter flounder distribution, which may have productivity and vulnerability implications. Apparent decreases in estuarine spawning or shifts toward coastal spawning (e.g., DeCelles and Cadrin 2010) may also have implications for vulnerability (e.g., less availability to recreational fisheries, decreasing vulnerability to that fishery) and productivity (possibly less larval retention). Consumption of winter flounder by other fishes, birds and mammal predators may be increasing as those predator populations increase.

The GOM assessment indicates that the stock is well above B_{MSY} and experiencing low fishing mortality. However, the GOM assessment is the most uncertain of the three (from a "feasibility" perspective, if not from a "statistical precision" perspective). The apparent shift in distribution to deeper habitat may be adding uncertainty to the stock assessment reference points that assume stationarity in vital rates. Therefore, it may be vulnerable to overfishing if managed at a catch level close to the nominally projected catch in the near term.

C. Major conflicting signals exist between the catch at age data and survey data within the modeling work. The split VPA is weighted towards the catch at age information while the preferred ASAP multi run has a greater weight on the survey information. Survey trends may not reflect the population changes in response to the large decline in the catch over time if a greater proportion of the population historically remained within the estuaries in the early 1980s where there is no survey coverage. This hypothesis could possible explain why the survey indices are relatively flat with little apparent response to the change in catch. However there is very limited data on the extent of estuarine residing populations in the 1980s. Therefore this hypothesis remains simply as speculation. The consequences of the split VPA being a better reflection of the true dynamics can be evaluated by assuming the catch or ABC from the preferred ASAP projection as taken within the split VPA projection formulation. Figure C78 is an example of the consequence of the split VPA model being true and assuming the catch from the 75% Fmsy ASAP multi projection.

Tor 9: Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

SDWG SAW 52 New Research Recommendations

1) Update and investigate migration rates between stock and movement patterns. The most recent comprehensive tagging study was completed in the 1960s (Howe and Coates), and a new large scale effort is warranted. Further investigate localized structure/genetics within the stocks.

2) Investigate the feasibility of port samplers collecting otoliths from large and lemon sole instead of scales because of problems under-ageing larger fish.

3) Investigate use of periodic gonad histology studies as a check to make ensure maturity estimates are accurate, with particular attention to obtaining sufficient samples from the Georges Bank stock.

4) Investigate the skipped spawning percentage for each stock, and estimate interannual variation when sufficient data have been collected.

5) Investigate ways to improve compliance to help VTR reporting. Currently about 300 of the 1500 permitted vessels consistently under-report the number of statistical area fished.

6) Encourage support for Industry Based Surveys, which can provide valuable information on stock abundance, distribution, and catchability in research surveys that is independent of and supplemental to NMFS efforts.

7).Explore use of a more complex Stock Synthesis model with small rates of migration between stocks.

8) Develop time series of winter flounder consumption by the major fish predators of winter

flounder.

9) Conduct studies to better understand recruitment processes of winter flounder, particularly in the GOM and on GBK.

10) Revise the NEFSC assessment software to include the ability to model S-R functions including environmental factors with errors/probabilities.

11) Further explore the relationship between large scale environmental forcing (e.g., temperature, circulation, climate) for effects on life history, reproduction, and recruitment in the Georges Bank stock.

12) Explore development of an index of winter flounder larval abundance based on MARMAP, GLOBEC, etc. time series.

Research Recommendations from GARM III

Assessment approaches needs to be explored that consider all three Winter Flounder stocks as a stock complex within which there is significant interaction amongst the individual stock components.

Working paper addressed by Terceiro MS (2011.) examined

Research Recommendations from SARC 36

1) The MADMF fall survey does collect winter flounder otoliths and scales, so ageing such material should be undertaken.

The MADMF fall survey has not been aged.

2) Increase the number of tows and/or consistently sample inshore strata in the NEFSC bottom trawl survey.

The number of tows in inshore Massachusetts strata conducted with the RV Bigelow starting in 2009 has increased from 1-2 tows to about 2-3 tows per strata with the exception of the fall 2010 survey which lacked sampling in Cape Cod bay. In addition stratum 64 appears to be more consistently sampled with the RV Bigelow and could possibly be included in the index in the future. However depth constraints prevents the sampling of stratum 58.

3) Increase MRFSS length sampling intensity in the recreational fishery.

Length sampling of the winter flounder B2 catch now occurs in the recreational fishery and was used in this assessment.

4) Increase temporal and market category coverage of length sampling in the commercial landings.

Biological length sampling in the ports has improved for all species. However the decline in commercial landings for Gulf of Maine winter flounder has made length sampling coverage by market category difficult. Unclassified sampling in the ports and observer sampling of the kept fish appears to have provided an adequate characterization of the size structure. However, regardless of increased observer coverage in 2010 the length sampling appears to have suffered from the decline in landings in 2010.

5) Increase the intensity of observer sampling especially with small- and large-mesh trawl gear.

Observer sampling has improved in the small and large mesh trawl fishery.

6) Examine the sources of discrepancy between NEFSC and MA survey maturity estimates.

Reasons for the discrepancy between NEFSC and MA survey maturity was examined by McBride et a.l MS 2011.

7) Initiate periodic maturity staging workshops, involving State and NEFSC trawl survey staff.

A maturity staging workshop was done with state and NEFSC staff. Education on how to stage maturity for winter flounder will need to continue as an ongoing process in the maturity workshops.

8) Incorporate the results from the MEDMR research trawl survey (begun in 2001) into the assessment as they become available.

Preliminary ME/NH survey winter flounder age data was examined by the SAW 52 SDWG. The ME/NH survey was included in the area swept estimates of 30+ biomass for this assessment.

9) Investigate derivation of stock-specific parameters for the next assessment.

It is not entirely clear on the intension of this research recommendation. Sensitivity of the assumed natural mortality was explored in this assessment.

10) Attempt use of a forward projection (statistical catch at age model) in the next assessment.

The forward projection ASAP model was developed and used in this assessment.

Research Recommendations prior to SARC 36

1) Examine the implications of anthropogenic mortalities caused by pollution and power plant entrainment in estimating yield per recruit, if feasible.

This research recommendation was not done. It is not clear how this research *recommendation could be addressed.*

2) Examine growth variations within the Gulf of Maine, using results from the Gulf of Maine Biological Sampling Survey (1993-1994).

This research recommendation is perhaps not needed with the aging of the relatively new ME/NH survey.

3) Further examine the stock boundaries to determine if Bay of Fundy winter flounder should be included in the Gulf of Maine stock complex.

This research recommendation has not been done. The Bay of Fundy seems to be an appropriate natural break for the stock complex. See working paper by DeCelles MS 2011.

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Table C1. Winter flounder commercial landings (metric tons) for Gulf of the Maine stock (U.S. statistical reporting areas 511 to 515). Landings from 1964-1977 is taken from SARC 21, 1982-1993 is re-estimated from the WODETS data, 1994-2010 is estimated using the trip based allocated AA tables.

Year	metric tons	Year	Metric tons
1964	1,081	1990	1,116
1965	665	1991	1,008
1966	785	1992	825
1967	803	1993	611
1968	864	1994	543
1969	975	1995	707
1970	1,092	1996	606
1971	1,113	1997	569
1972	1,085	1998	643
1973	1,080	1999	350
1974	885	2000	535
1975	1,181	2001	698
1976	1,465	2002	683
1977	2,161	2003	754
1978	2,194	2004	623
1979	2,021	2005	335
1980	2,437	2006	199
1981	2,407	2007	254
1982	2,793	2008	287
1983	2,096	2009	283
1984	1,699	2010	140
1985	1,582		
1986	1,188		
1987	1,140		
1988	1,250		
1989	1,253		

Table C2. Gulf of Maine winter flounder commercial landings (metric tons) by gear.

Year	Trawl	*Shrimp*	Gillnet	Other	Total
1982	2,485	151	59	99	2,793
1983	1,819	142	54	80	2,096
1984	1,438	139	26	96	1,699
1985	1,446	62	16	59	1,582
1986	912	69	164	42	1,188
1987	848	97	135	60	1,140
1988	1,016	61	161	12	1,250
1989	1,008	58	138	48	1,253
1990	857	25	214	21	1,116
1991	868	22	94	25	1,008
1992	632	17	160	16	825
1993	460	1	138	13	611
1994	438	0	100	5	543
1995	511	1	184	10	706
1996	464	0	135	6	606
1997	426	0	134	9	569
1998	461	0	176	6	643
1999	248	0	101	1	350
2000	412	0	122	1	535
2001	529	0	160	9	698
2002	585	0	82	15	682
2003	564	0	185	5	754
2004	427	0	137	59	623
2005	230	0	67	38	335
2006	133	0	47	19	199
2007	162	0	53	38	254
2008	195	0	57	35	287
2009	202	0	67	14	283
2010	83	0	49	7	140

Table C3. Estimated number (000's) and MRFSS estimated weight and predicted weight (mt) from length frequencies for Gulf of Maine winter flounder caught, landed, and discarded in the recreational fishery.

	Number (000's)				Metric tons	
	Catch A+B1+B2	Landed A+B1	Released B2	15% Release Mortality	MRFSS Landed A+B1	Predicted Landed
1981	6,200	5,433	767	115	2,554	2,270
1982	8,207	7,274	933	140	1,876	3,024
1983	2,169	1,988	181	27	868	817
1984	2,477	2,285	191	29	1,300	1,103
1985	3,694	3,220	474	71	1,896	1,629
1986	946	691	255	38	523	411
1987	3,070	2,391	679	102	1,809	1,443
1988	953	841	111	17	345	537
1989	1,971	1,678	294	44	620	1,035
1990	786	652	134	20	370	344
1991	213	154	59	9	91	86
1992	186	137	48	7	90	77
1993	398	249	150	22	140	134
1994	232	145	88	13	83	77
1995	150	83	67	10	40	40
1996	183	98	86	13	56	52
1997	192	64	129	19	43	32
1998	109	65	44	7	30	27
1999	109	65	44	7	33	34
2000	146	59	87	13	32	31
2001	173	72	102	15	45	37
2002	101	61	40	6	42	35
2003	86	52	34	5	32	29
2004	61	41	20	3	19	29
2005	79	40	39	6	25	24
2006	94	53	41	6	34	35
2007	74	48	26	4	28	26
2008	243	168	74	11	104	103
2009	214	115	100	15	65	67
2010	168	107	61	9	48	48

Table C4. Number of lengths, samples, and metric tons per sample for Gulf of Maine winter flounder. Number of samples and calculations of metric tons per sample does not include observer data or gillnet landings from 1990-2007. * = redistributed according to market category and half year proportions. Bold numbers have additional lengths from observer trawl data but are not included in the number of samples.

		Number of lengths.						Number of samples						mt/samples				
year	half	lg	sm	med	un	total	half	lg	sm	med	un	total	half	lg	sm	med	un	total
1982	1	102	101		455		1	1	1		4		1	838	453		46	
	2	84	81		106	929	2	1	1		1	9	2	396	691		231	310
1983	1	380	100	99	407		1	4	1	1	4		1	120	510		53	
	2	115	1344		106	2551	2	2	11		1	24	2	125	44	64	95	87
1984	1	438	503		221		1	5	4		2		1	74	95			
	2	126	813	100		2201	2	1	6	1		19	2	189	67	114	124	89
1985	1	665	735				1	6	5				1	54				
	2	121			80	1601	2	2			1	14	2	87		182	176	113
1986	1	237	109	109	266		1	3	1	1	3		1		242	126	48	
	2		500	193	89	1503	2		6	2	1	17	2	113	37	31	56	70
1987	1				113		1				1		1					
	2	47	251	272		683	2	1	3	3		8	2	257	137	75	249	143
1988	1	102	258	706	*		1	1	3	7	*		1		108	23		
	2		169	107	*	1342	2		2	1	*	14	2	340	164	96		89
1989	1	113		91	**234**		1	1		1	**1**		1			168		
	2		95	220	**32**	785	2		1	2		6	2	313	435	42	**254**	209
1990	1	328	301		102		1	3	4		1		1	64	48			
	2	117	197	97		1142	2	1	2	1		12	2	83	90	144	111	75
1991	1	188	254	205	**143**		1	2	2	2	**2**		1	91	72			
	2	236	349			1375	2	3	3			14	2	32	62	95	57	65
1992	1	246	100	93	**107**		1	3	1	1			1					
	2	57	74	253		930	2	1	1	3		10	2	54	126	35		66
1993	1	100		288	**91**		1	1		3			1	84		17		
	2	80	55	157	**51**	822	2	1	1	2		8	2	47	178	30		59

Table C4. Continued.

	Number of lengths.							Number of samples						mt/samples					
year	half	lg	sm	med	un	total	half	lg	sm	med	un	total	half	lg	sm	med	un	total
1994	1		71	92			1		1	1			1			57		
	2	94		235	*	492	2	1		3		6	2	118	157	18		64
1995	1	101		474	**33**	474	1	1		5			1			29		
	2			414	**609**	1631	2			4		10	2	94		59		52
1996	1		378				1		4				1		29			
	2		795	338	**112**	1623	2		7	4		15	2		23	16		31
1997	1		127	75	*		1		2	1	*		1		34	33		
	2	407	1014	218	*	1841	2	5	11	3	*	22	2	20	11	19		18
1998	1		299	280	*		1		5	3	*		1		16	16		
	2	69	746	110	*	1504	2	1	9	1	*	19	2	51	12	32		17
1999	1			275	**122**		1			3			1					
	2		80		**430**	907	2		2			5	2		42	15		50
						552												
2000	1	104	4331	250	**1046**		1	1	59	4			1	19	1			
	2	244	344		**130**	6449	2	4	6		**1**	75	2	7	20	24		6
2001	1		89	474	**795**		1		1	6			1		66	10		
	2		254	250	**1756**	3618	2		3	3		13	2		35	47		41
2002	1	28	507	173	**573**		1	1	7	2	**1**		1		7	34	**59**	
	2		982	133	**2734**	5130	2		14	2	**2**	29	2	57	14	48	**35**	21
2003	1		744		**2410**		1	1	10	1	**2**		1		11		**48**	
	2	384	818	110	**914**	5380	2	12	19	1	**6**	52	2	3	9	28	**18**	11
2004	1	223	692	86	**1915**		1	7	14	1	**6**		1		6		**12**	
	2	7	706		**2955**	6584	2	1	12		**4**	45	2	18	9	48	**6**	11
2005	1		269		**3202**		1		4		**11**		1		16.8		**3**	
	2	600	807		**5696**	10574	2	10	7		**11**	43	2	11	10		**2**	9
2006	1		732		**2330**		1		3		**11**		1		7		**1**	
	2	341	281		**823**	4507	2	4	3		**9**	30	2	14	14		**13**	9
2007	1		296		**1316**		1		3		**3**		1		11.3		**6**	
	2	15	272		**831**	2730	2	1	3		**3**	13	2	54	24.7		**4**	15

Table C5. Number of kept observer lengths, trips, and gillnet metric tons landed per 100 lengths sampled for Gulf of Maine winter flounder by half year.

Year	half	lengths	trips	gillnet landings	Mt/100 lengths
1990	1	500	90	185	
	2	78	1	29	
		578	91	215	37
1991	1	167	6	85	
	2	30	8	12	
		197	14	97	49
1992	1	1925	39	135	
	2	172	25	25	
		2097	64	160	8
1993	1	1990	63	97	
	2	375	20	42	
		2365	83	139	6
1994	1	330	22	75	
	2	207	10	25	
		537	32	100	19
1995	1	1132	20	156	
	2	275	23	28	
		1407	43	184	13
1996	1	930	26	114	
	2	118	17	22	
		1048	43	136	13
1997	1	656	18	105	
	2	42	4	29	
		698	22	134	19
1998	1	1163	19	145	
	2	431	8	31	
		1594	27	176	11
1999	1	747	5	84	
	2	538	12	17	
		1285	17	101	8
2000	1	911	8	104	
	2	259	4	18	
		1170	12	122	10

year	half	lengths	trips	gillnet landings	Mt/100 lengths
2001	1	862	15	124	
	2	42	2	36	
		904	17	160	18
2002	1	237	13	37	16
	2	691	31	45	7
		928	44	82	9
2003	1	1702	41	89	5
	2	3041	47	96	3
		4743	88	185	4
2004	1	2255	59	62	3
	2	4605	145	75	2
		6860	204	137	2
2005	1	635	31	26	4
	2	3982	134	41	1
		4617	165	67	1
2006	1	385	16	25	6
	2	174	14	21	12
		559	30	47	8
2007	1	651	20	26	4
	2	875	22	27	3
		1526	42	52	3
2008	1	165	14	31	3
	2	134	26	26	3
		499	40	57	6
2009	1	288	40	29	10
	2	476	58	38	8
		764	49	67	8
2010	1	689	15	19	3
	2	147	26	30	20
		836	49	49	6

Table C6. Gulf of Maine winter flounder estimated discard ratios in the shrimp fishery (total discard kg / total days fished) estimated from NEFSC and MA Observer data by shrimp season. Ratio for 1982-1988 is the average ratio from 1989-1992. Total shrimp fishery days fished and estimated discards are also shown. A 50% mortality is used for estimating dead discards. Dotted line indicates the introduction of the Nordmore grate.

Year	trips	tows	ratio	Shrimp df	discard wt (kg)	dead discards (kg)
1982			*13.5*	970	13,120	6,560
1983			*13.5*	1157	15,646	7,823
1984			*13.5*	1754	23,721	11,860
1985			*13.5*	2081	28,149	14,074
1986			*13.5*	2395	32,391	16,196
1987			*13.5*	3708	50,149	25,075
1988			*13.5*	2815	38,072	19,036
1989	12	24	3.5	2840	10,023	5,011
1990	25	53	13.1	3205	41,853	20,927
1991	38	94	16.3	2588	42,265	21,132
1992	72	225	21.2	2313	48,978	24,489
1993	63	178	7.0	1902	13,401	6,700
1994	63	183	5.8	1982	11,586	5,793
1995	58	136	4.8	3376	16,186	8,093
1996	40	92	4.0	3243	13,126	6,563
1997	21	55	7.5	3661	27,391	13,695
1998	3	6	3.9	2204	8,526	4,263
1999	4	5	1.4	1217	1,696	848
2000	4	10	7.7	793	6,091	3,046
2001	4	6	6.1	673	4,095	2,048
2002	1	2	2.4	246	581	291
2003	18	36	8.7	532	4,628	2,314
2004	11	47	8.5	304	2,588	1,294
2005	17	47	15.9	313	4,973	2,486
2006	17	55	12.7	170	2,162	1,081
2007	14	60	4.1	470	1,931	966
2008	19	72	8.1	620	5,049	2,524
2009	12	49	17.7	333	5,905	2,953
2010	15	45	5.6	708	4,000	2,000

Table C7. Gulf of Maine winter flounder re-estimated large and small mesh trawl and gillnet discard ratios (discard/sum all species kept), estimated discard CVs, and estimated discards in metric tons.

	Discard Ratio			CV			Metric Tons		
	trawl			trawl			trawl		
year	lg mesh	sm mesh	gillnet	lg mesh	sm mesh	gillnet	lg mesh	sm mesh	gillnet
1989	0.0011	0.0032	0.0006	0.53	0.55	0.34	21.94	5.73	8.96
1990	0.0004	0.0001	0.0027	0.54	1.00	0.44	10.70	0.30	44.79
1991	0.0011	0.0010	0.0005	0.45	0.60	0.23	34.18	2.38	6.37
1992	0.0005	0.0002	0.0020	0.38	0.86	0.14	14.37	0.46	26.13
1993	0.0003	0.0040	0.0023	0.79	0.95	0.17	7.90	9.99	38.13
1994	0.0000	0.0000	0.0008			1.66	0.00		10.78
1995	0.0009	0.0092	0.0016	0.55	0.43	0.45	15.12	20.67	23.86
1996	0.0002	0.0008	0.0008	1.77	0.28	0.59	4.23	2.28	10.99
1997	0.0001	0.0105	0.0058	0.62	0.01	0.61	1.61	19.89	71.29
1998	0.0011	0.0000	0.0010	0.45		0.46	14.93		13.15
1999	0.0017	0.0081	0.0010	0.34	0.29	0.51	18.67	13.98	7.85
2000	0.0004	0.0000	0.0029	0.87		0.39	6.06		23.28
2001	0.0016	0.0023	0.0008	0.39	1.32	0.66	26.33	3.21	5.65
2002	0.0022	0.0087	0.0015	0.36	0.41	0.41	34.31	11.22	9.82
2003	0.0014	0.0016	0.0008	0.33	0.50	0.32	25.40	0.84	5.15
2004	0.0023	0.0081	0.0011	0.29	0.30	0.27	60.78	3.15	7.65
2005	0.0025	0.0100	0.0003	0.27	0.69	0.22	46.95	3.14	2.21
2006	0.0019	0.0038	0.0001	0.32	0.43	0.42	20.89	1.75	0.85
2007	0.0032	0.0052	0.0002	0.33	0.42	0.39	29.73	3.37	1.33
2008	0.0015	0.0015	0.0002	0.24	0.49	0.43	17.12	1.12	1.76
2009	0.0015	0.0137	0.0003	0.19	0.42	0.29	16.19	9.57	2.31
2010	0.0004	0.0228	0.0001	0.26	0.35	0.16	4.74	25.70	0.83

Table C8. Gulf of Maine winter flounder observer numbers of lengths

	Kept			Discards			
year	lg mesh trawl	sm mesh trawl	gillnet	shrimp	lg mesh trawl	sm mesh trawl	gillnet
1989	56	4	76	426	78	183	2
1990	-	-	578	126	-	-	331
1991	42	-	197	1,144	9	-	35
1992	107	-	2,097	1,013	17	-	371
1993	51	91	2,379	1,687	12	43	437
1994	-	-	537	980	-	-	141
1995	642	-	1,438	716	30	258	209
1996	100	-	1,393	301	5	184	91
1997	-	10	849	155	2	-	67
1998	-	-	1,594	-	-	-	70
1999	552	-	1,285	-	-	231	112
2000	1,100	1	1,170	-	90	-	220
2001	2,615	-	904	-	192	-	42
2002	2,845	41	930	-	924	481	52
2003	2,497	175	4,751	265	1,535	168	246
2004	2,857	950	6,864	278	1,549	779	532
2005	6,222	189	4,618	168	3,074	393	131
2006	2,348	37	559	268	955	74	19
2007	2,097	-	1,526	17	2,188	162	44
2008	3,352	-	499	214	1,714	1	47
2009	1,629	-	764	53	643	520	58
2010	270	-	836	49	270	437	21

Table C9. Gulf of Maine winter flounder updated number of trips in the large and small mesh trawl and gillnet fishery in the dealer and observer data.

	Large Mesh Trawl						Small Mesh Trawl						Gillnet					
	Dealer trips		Ob trips		Dealer	Ob	Dealer trips		Ob trips		Dealer	Ob	Dealer trips		Ob trips		Dealer	Ob
YEAR	half 1	half 2	half 1	half 2	sum	sum	half 1	half 2	half 1	half 2	sum	sum	half 1	half 2	half 1	half 2	sum	sum
1989	6,561	5,992	16	21	12,553	37	192	1,570	7	16	1,762	23	4,140	5,616		84	9,756	84
1990	6,258	6,283	10	16	12,541	26	77	1,750		8	1,827	8	3,771	6,349	64	56	10,119	120
1991	7,181	6,705	12	36	13,886	48	59	1,574		29	1,633	29	3,488	5,365	153	648	8,853	801
1992	7,682	6,396	33	11	14,078	44	66	2,079	3	12	2,145	15	3,576	5,302	357	539	8,878	896
1993	6,548	6,153	9	8	12,700	17	86	1,913	2	4	1,999	6	3,431	5,801	251	309	9,232	560
1994	6,633	5,688	4	2	12,321	6	154	2,323			2,476		3,661	6,719	55	30	10,380	85
1995	6,171	4,983	17	7	11,154	24	639	1,191		30	1,829	30	4,448	5,884	23	46	10,332	69
1996	5,813	4,677	8	3	10,490	11	54	1,436	2	38	1,489	40	3,308	4,983	21	25	8,292	46
1997	4,814	3,860	4	1	8,674	5	142	1,075	3		1,216	3	3,015	4,187	13	20	7,201	33
1998	5,445	4,226	6		9,671	6	37	754			791		3,120	4,005	29	49	7,125	78
1999	3,441	4,007	1	21	7,448	22	28	769		11	797	11	1,981	2,540	18	55	4,521	73
2000	4,245	4,923	48	32	9,168	80	55	595			649		2,169	3,271	41	40	5,440	81
2001	4,321	4,977	36	75	9,297	111	71	600	1	3	671	4	2,325	3,382	25	22	5,707	47
2002	3,617	5,247	28	121	8,863	149	42	571	1	33	614	34	1,632	3,963	23	57	5,595	80
2003	3,142	5,274	116	135	8,416	251	44	270	7	12	313	19	2,156	3,912	93	202	6,068	295
2004	2,768	4,203	68	182	6,971	250	17	216	13	55	233	68	1,980	3,282	156	619	5,262	775
2005	2,369	3,600	171	328	5,969	499	29	160	20	49	189	69	1,500	4,010	138	513	5,509	651
2006	2,100	3,132	141	62	5,232	203	21	223	14	10	244	24	1,578	3,869	74	54	5,447	128
2007	2,484	2,817	100	125	5,302	225	41	406	1	15	447	16	1,920	4,554	32	86	6,474	118
2008	3,200	2,802	102	152	6,002	254	182	384		12	567	12	2,778	5,111	42	108	7,889	150
2009	2,950	3,319	196	214	6,269	410	10	412		22	422	22	2,783	5,606	120	156	8,389	276
2010	2,839	1,354	168	440	4,193	608	220	487	1	29	707	30	3,423	3,341	259	980	6,764	1,239

Table C10. SARC 52 Gulf of Maine winter flounder catch at age construction summary.

Catch at age Component	years	Half yr	length data	age data
trawl and other commercial landings	82-98	mix	commercial and observer (unclassified)	commercial
trawl and other commercial landings	99-10	Whole (99-01) Half yr (02-10)	Observer (Trawl kept) Com unclassified trawl	commercial
gillnet commercial Landings	90-10	whole (99-01) Half yr (02-10)	observer (gillnet kept) Com unclassified gillnet	commercial
recreational Landings	82-10	Half yr	MRFSS/MRIP	combine NEFSC and MA DMF ages by half yr
Recreational Discards	82-06	Half yr	spr & fall MA DMF	combine NEFSC and MA DMF ages by half yr
Recreational Discards	07-10	whole yr	MRFSS	combine NEFSC spr & fall survey
Large mesh trawl Discards (survey filter)	82-88	whole yr	survey method (spr & fall MA DMF)	Combine NEFSC spr & fall survey
large mesh trawl disc (obs disc/keptall)	89-10	whole yr	survey method (89-00) observer disc (01-10)	combine NEFSC spr & fall survey
gillnet discards (*obs* disc/keptall)	86-10	Whole yr	observer discards	combine spr NEFSC and MA DMF ages for 1986-2001 (combine NEFSC spr & fall survey for 2002-2010)
shrimp discards (obs disc/days fished)	82-10	shrimp season	observer (discards)	combine spr NEFSC and MA DMF ages

Table C11. Gulf of Maine winter flounder large and small mesh trawl and gillnet kept ratios (kept/sum all species kept), estimated discard CVs, and estimated landings in metric tons.

	Kept Ratio			CV			Metric Tons		
	trawl			trawl			trawl		
year	lg mesh	sm mesh	gillnet	lg mesh	sm mesh	gillnet	lg mesh	sm mesh	gillnet
1989	0.006	0.015	0.007	0.39	0.44	0.38	128	27	107
1990	0.002	0.000	0.015	0.46	0.73	0.43	43	1	246
1991	0.019	0.001	0.003	0.44	0.51	0.22	573	2	42
1992	0.008	0.001	0.013	0.49	0.58	0.12	228	4	170
1993	0.004	0.026	0.014	0.76	0.54	0.14	93	65	236
1994	0.001	0.000	0.005	0.88		1.00	13	0	73
1995	0.031	0.000	0.005	1.05		0.28	542	0	84
1996	0.016	0.000	0.007	2.45		0.42	288	0	94
1997	0.001	0.043	0.020	1.05	0.03	0.53	12	81	249
1998	0.005	0.000	0.009	0.42		0.39	65	0	126
1999	0.107	0.000	0.007	0.31		0.46	1213	0	56
2000	0.011	0.000	0.021	0.42		0.41	168	0	168
2001	0.025	0.000	0.011	0.25		0.74	409	0	81
2002	0.029	0.006	0.046	0.29	0.47	0.39	457	8	302
2003	0.020	0.012	0.033	0.19	0.54	0.18	368	7	220
2004	0.031	0.039	0.026	0.20	0.58	0.12	837	15	183
2005	0.022	0.018	0.012	0.15	0.30	0.14	407	6	78
2006	0.019	0.002	0.002	0.27	0.39	0.41	216	1	11
2007	0.012	0.002	0.013	0.19	0.35	0.37	114	2	94
2008	0.012	0.001	0.002	0.20	0.71	0.33	135	1	21
2009	0.012	0.000	0.004	0.19		0.23	123	0	39
2010	0.004	0.000	0.004	0.30	0.93	0.12	40	0	26

Table C12. Gulf of Maine winter flounder composition of the catch by number (000's).

	Landings		Discards				
year	recreational	commercial	recreational	gillnet	lg mesh	shrimp	Total
1982	7,274	5,282	140		1,397	56	14,149
1983	1,988	3,842	27		428	67	6,353
1984	2,285	3,992	29		249	102	6,657
1985	3,220	2,965	71		340	121	6,717
1986	691	2,055	38	45	253	139	3,221
1987	2,391	2,086	102	45	308	216	5,146
1988	841	2,210	17	45	406	164	3,682
1989	1,678	2,329	44	16	42	61	4,171
1990	652	1,981	20	84	20	113	2,870
1991	154	1,844	9	12	64	165	2,247
1992	137	1,620	7	44	27	241	2,078
1993	249	1,440	22	70	16	83	1,880
1994	145	1,153	13	24	23	86	1,443
1995	83	1,501	10	31	29	94	1,748
1996	98	1,228	13	21	8	59	1,427
1997	64	1,101	19	128	18	175	1,504
1998	65	1,147	7	24	28	53	1,323
1999	65	605	7	7	31	11	725
2000	59	940	13	39	11	38	1,100
2001	72	1,160	15	9	52	25	1,333
2002	61	1,126	6	11	72	3	1,279
2003	51	1,257	5	8	52	25	1,398
2004	41	996	3	12	137	15	1,203
2005	40	551	6	4	94	26	721
2006	53	317	6	1	40	10	426
2007	48	412	4	2	57	9	531
2008	168	477	11	2	34	20	712
2009	115	471	15	3	29	26	659
2010	107	219	9	1	7	22	365

Table C13. Gulf of Maine winter flounder composition of the catch by weight (mt).

	Landings		Discards				
year	recreational	commercial	recreational	gillnet	lg mesh	shrimp	Total
1981	2,270						
1982	3,024	2,793	11		343	7	6,178
1983	817	2,096	2		112	8	3,035
1984	1,103	1,699	3		67	12	2,883
1985	1,629	1,582	8		93	14	3,327
1986	411	1,185	5	12	63	16	1,692
1987	1,443	1,140	12	12	81	25	2,713
1988	537	1,250	2	12	106	19	1,927
1989	1,035	1,253	6	4	11	5	2,315
1990	344	1,116	3	22	5	21	1,511
1991	86	1,008	1	3	17	21	1,136
1992	77	825	1	12	7	24	947
1993	134	611	3	19	4	7	778
1994	77	543	2	6	6	6	640
1995	40	707	1	12	8	8	776
1996	52	606	2	6	2	7	674
1997	32	569	3	38	5	14	660
1998	27	643	1	7	7	4	689
1999	34	350	1	4	9	1	399
2000	31	535	2	12	3	3	587
2001	37	698	3	3	14	2	756
2002	35	682	1	5	17	0	740
2003	29	754	1	3	13	2	801
2004	29	623	0	4	31	1	687
2005	24	335	1	1	23	2	387
2006	35	199	1	0	10	1	247
2007	26	254	1	1	15	1	297
2008	103	287	3	1	9	3	405
2009	67	283	5	1	8	3	367
2010	48	140	3	0	2	2	195

Table C14. Gulf of Maine winter flounder landing at age (000's).

year	1	2	3	4	5	6	7	8+
1982	40	2,097	4,551	3,468	1,401	617	276	104
1983	93	748	1,680	1,799	856	362	158	133
1984	12	765	1,935	1,829	852	348	312	225
1985	0	137	1,335	2,039	1,922	398	218	136
1986	0	327	731	812	359	353	102	62
1987	0	312	1,626	1,161	792	311	138	136
1988	2	337	848	1,046	359	248	123	89
1989	0	162	1,309	1,462	774	212	51	38
1990	0	216	721	950	496	172	49	29
1991	0	186	782	580	232	119	57	41
1992	0	207	657	569	205	72	28	18
1993	0	132	688	644	145	68	9	3
1994	0	8	466	608	149	44	16	7
1995	0	8	291	744	387	120	16	18
1996	0	176	706	336	76	13	7	11
1997	0	150	499	382	92	22	8	12
1998	0	26	232	458	328	115	40	12
1999	0	0	61	229	224	101	29	27
2000	0	5	59	375	371	140	34	15
2001	0	0	52	358	425	239	101	56
2002	0	3	135	364	401	185	65	34
2003	0	5	140	378	415	246	78	46
2004	0	32	125	328	248	194	64	47
2005	0	12	120	239	135	53	17	16
2006	0	2	79	149	86	27	14	12
2007	0	7	68	173	130	57	16	9
2008	0	1	51	171	201	115	66	40
2009	0	1	25	133	216	144	41	26
2010	0	0	11	62	114	83	40	16

Table C15. Gulf of Maine winter flounder discards at age (000's).

year	1	2	3	4	5	6	7	8+
1982	72	786	716	19	0	0	0	0
1983	42	167	275	38	0	0	0	0
1984	11	151	142	72	4	0	0	0
1985	31	151	263	83	3	0	0	0
1986	49	178	196	39	14	0	0	0
1987	53	174	378	63	2	0	0	0
1988	22	134	340	131	3	1	0	0
1989	24	77	43	16	3	1	0	0
1990	9	47	114	58	8	0	0	0
1991	18	117	82	30	2	0	0	0
1992	44	182	77	15	1	0	0	0
1993	28	64	70	25	4	0	0	0
1994	18	73	37	15	3	0	0	0
1995	27	62	44	22	5	2	1	0
1996	16	41	27	14	2	0	0	0
1997	19	136	93	66	26	0	0	0
1998	20	38	32	16	4	0	1	0
1999	7	13	18	11	3	2	1	1
2000	17	24	30	19	9	2	0	0
2001	13	21	32	26	7	3	0	0
2002	4	28	32	20	6	2	0	0
2003	9	36	28	11	4	1	0	1
2004	10	57	77	17	2	2	1	0
2005	15	42	46	20	4	2	0	0
2006	7	12	25	11	2	0	0	0
2007	5	16	25	21	5	0	0	0
2008	8	20	24	10	3	1	0	0
2009	6	22	29	13	3	0	0	0
2010	6	10	8	8	5	2	0	0

Table C16. Gulf of Maine winter flounder total catch at age (000's).

year	1	2	3	4	5	6	7	8+
1982	112	2,883	5,267	3,487	1,402	617	276	104
1983	135	915	1,955	1,838	857	362	158	133
1984	23	916	2,077	1,901	856	348	312	225
1985	31	288	1,598	2,122	1,925	398	218	136
1986	49	505	928	851	373	353	102	62
1987	53	486	2,004	1,224	794	311	138	136
1988	23	471	1,188	1,177	361	248	123	89
1989	24	238	1,353	1,478	777	213	51	38
1990	9	263	836	1,008	504	172	49	29
1991	18	304	864	610	234	119	57	41
1992	44	390	734	585	207	72	28	18
1993	28	197	758	669	149	69	9	3
1994	18	81	503	623	152	44	16	7
1995	27	70	335	765	392	122	18	18
1996	16	217	733	350	79	13	7	11
1997	19	286	592	449	117	22	8	12
1998	20	64	264	474	333	115	41	12
1999	7	13	79	240	227	103	29	28
2000	17	29	89	394	380	142	34	15
2001	13	21	84	384	432	242	101	56
2002	4	31	167	383	408	187	65	34
2003	9	41	168	390	419	247	78	46
2004	10	89	202	345	250	195	64	47
2005	15	54	165	259	139	55	17	16
2006	7	14	104	160	89	27	14	12
2007	5	23	93	193	135	57	16	9
2008	8	21	75	181	205	116	66	40
2009	6	22	54	146	219	144	41	26
2010	6	10	20	70	120	84	40	16

Table C17. Gulf of Maine winter flounder mean weights at age.

year	1	2	3	4	5	6	7	8+
1982	0.084	0.224	0.375	0.487	0.595	0.802	0.943	2.037
1983	0.123	0.257	0.358	0.502	0.644	0.795	0.946	1.164
1984	0.082	0.264	0.306	0.401	0.543	0.708	0.855	1.115
1985	0.043	0.174	0.312	0.447	0.584	0.809	0.927	1.122
1986	0.050	0.309	0.410	0.510	0.664	0.813	1.005	1.221
1987	0.035	0.259	0.392	0.527	0.690	0.858	1.070	1.284
1988	0.038	0.396	0.426	0.487	0.648	0.754	1.022	1.204
1989	0.040	0.229	0.427	0.582	0.629	1.004	1.175	1.397
1990	0.034	0.301	0.421	0.538	0.625	0.763	0.979	1.226
1991	0.038	0.277	0.451	0.583	0.599	0.695	0.744	0.929
1992	0.027	0.227	0.406	0.533	0.638	0.788	1.051	1.465
1993	0.028	0.238	0.367	0.439	0.645	0.667	1.115	1.453
1994	0.028	0.090	0.369	0.470	0.610	0.747	1.068	1.229
1995	0.038	0.105	0.341	0.421	0.535	0.635	0.833	1.563
1996	0.028	0.321	0.454	0.541	0.643	0.722	0.767	1.321
1997	0.038	0.240	0.421	0.512	0.628	0.889	0.784	0.921
1998	0.029	0.202	0.392	0.472	0.615	0.755	0.910	1.557
1999	0.039	0.114	0.377	0.487	0.542	0.665	0.838	1.219
2000	0.041	0.146	0.353	0.473	0.581	0.698	0.817	1.030
2001	0.034	0.115	0.319	0.448	0.538	0.693	0.852	1.194
2002	0.050	0.182	0.415	0.496	0.593	0.705	0.882	1.285
2003	0.035	0.156	0.366	0.482	0.560	0.704	0.889	1.436
2004	0.035	0.207	0.352	0.494	0.628	0.763	0.923	1.269
2005	0.042	0.172	0.380	0.505	0.669	0.895	1.038	1.346
2006	0.048	0.138	0.404	0.535	0.715	0.811	1.032	1.365
2007	0.043	0.200	0.386	0.487	0.639	0.815	0.964	1.476
2008	0.046	0.153	0.375	0.474	0.549	0.671	0.784	1.097
2009	0.043	0.155	0.329	0.449	0.565	0.678	0.692	1.115
2010	0.031	0.065	0.314	0.427	0.507	0.604	0.717	0.947

Table C18. NEFSC and MDMF survey indices of abundance for Gulf of Maine winter flounder. Indices are stratified mean number and mean weight (kg) per tow. NEFSC indices are for inshore strata (58,59,60,61,65,66) and offshore strata (26,27,38,39,40). NEFSC indices are calculated with trawl door conversion factors where appropriate. NEFSC GOM Length based conversions were applied in 2009 and 2010. NEFSC fall 2010 (bold) did not sample Cape Cod Bay. MA DMF uses strata 25-36.

	NEFSC spring		NEFSC fall		MA spring		MA fall	
year	number	weight	number	weight	number	weight	number	weight
1978					98.556	20.772	59.152	12.741
1979	4.487	1.730	6.003	2.602	71.834	15.787	134.251	32.837
1980	5.586	2.391	13.141	6.553	72.142	19.108	83.805	17.868
1981	6.461	2.122	4.179	3.029	106.341	30.383	50.847	13.595
1982	7.670	3.022	4.201	1.924	61.612	14.713	108.203	24.418
1983	12.367	5.653	10.304	3.519	112.487	28.984	76.658	15.143
1984	5.155	1.979	7.732	3.106	68.949	16.716	39.541	12.212
1985	3.469	1.418	7.638	2.324	54.210	15.302	48.677	8.288
1986	2.342	0.998	2.502	0.938	68.984	16.352	44.646	6.920
1987	5.609	1.503	1.605	0.488	85.180	18.640	54.434	8.018
1988	6.897	1.649	3.000	1.030	54.039	11.266	38.419	8.237
1989	3.717	1.316	6.402	2.013	64.696	13.940	39.249	8.602
1990	5.415	2.252	3.527	1.177	82.125	14.375	67.661	13.218
1991	4.517	1.436	7.035	1.467	46.630	11.513	101.716	17.580
1992	3.932	1.160	10.447	3.096	79.000	15.356	87.581	15.089
1993	1.556	0.353	7.559	1.859	78.018	12.051	93.527	15.109
1994	3.481	0.891	4.870	1.319	72.578	9.779	67.789	13.246
1995	12.185	3.149	4.765	1.446	89.361	14.960	76.736	15.092
1996	2.736	0.732	10.099	3.116	70.494	12.082	77.006	13.144
1997	2.806	0.664	10.008	2.950	85.396	12.959	78.402	14.438
1998	2.001	0.527	3.218	0.987	77.771	13.473	98.450	15.454
1999	6.510	1.982	10.921	3.269	80.776	14.957	125.742	23.204
2000	10.383	2.885	12.705	5.065	162.190	34.160	99.953	25.100
2001	5.242	1.663	8.786	3.133	89.743	24.510	81.072	17.743
2002	12.066	3.692	10.691	4.003	91.083	22.391	65.812	16.264
2003	7.839	2.544	10.182	4.315	83.693	17.323	90.477	15.801
2004	3.879	1.103	2.763	0.867	79.115	11.201	107.591	14.091
2005	6.920	2.056	8.807	2.314	94.044	11.980	78.591	11.812
2006	4.173	1.211	7.117	2.346	85.548	14.434	86.985	15.463
2007	2.500	0.717	6.378	1.820	53.583	10.060	76.669	11.599
2008	11.543	2.177	13.319	4.692	46.863	8.424	90.919	18.085
2009	6.846	2.100	13.176	4.721	71.316	12.277	108.996	22.677
2010	5.023	1.425	***12.046***	***3.922***	68.235	13.676	104.672	18.612

Table C19. Forward and backward calculation Plus group diagnostic report from the split VPA for Gulf of Maine winter flounder.

Year	Population Backward	Population Forward	F Forward	F Backward	Ratio
1982	255	255	0.63	0.63	1.00
1983	403	369	0.53	0.47	0.89
1984	569	381	1.09	0.60	0.55
1985	238	416	0.47	1.04	2.22
1986	183	293	0.28	0.49	1.75
1987	263	301	0.72	0.88	1.22
1988	188	190	0.76	0.77	1.01
1989	64	155	0.33	1.10	3.33
1990	50	104	0.39	1.05	2.73
1991	71	74	0.98	1.06	1.09
1992	33	46	0.60	0.94	1.58
1993	6	34	0.11	0.91	8.40
1994	17	27	0.35	0.61	1.76
1995	24	30	1.10	1.72	1.57
1996	43	15	1.73	0.35	0.20
1997	56	14	2.60	0.28	0.11
1998	27	21	1.00	0.72	0.72
1999	98	39	1.64	0.39	0.24
2000	45	56	0.36	0.48	1.31
2001	129	76	1.69	0.68	0.40
2002	85	97	0.51	0.61	1.20
2003	90	108	0.66	0.87	1.31
2004	89	89	0.91	0.91	1.00
2005	47	63	0.35	0.50	1.44
2006	87	55	0.29	0.17	0.60
2007	51	94	0.12	0.23	1.95
2008	167	115	0.50	0.32	0.64
2009	108	199	0.16	0.32	1.97
2010	101	217	0.09	0.20	2.26
2011	232	318	N/A	N/A	

Table C20. Summary results of GOM Winter Flounder ASAP model runs. Run 2 is the preferred ASAP multi run.

Model Run #	1	2	3	4	5
Year	1982-2010	1982-2010	1982-2010	1982-2010	1982-2010
Model Desc.	No Time Blocks in Selectivity; Weighting = 50	Two Block Fishery Selectivity fixed at Ages 5 in B1 and Age5 in B2; Weighting = 50	Two Block Fishery Selectivity fixed at Ages 4 in B1 and Age5 in B2; Weighting = 50; Modify ages fixed in Survey Selectivity_VERSION2; Lower Fixed Ages in Fishery Selectivity	**Run 3 + Force a Flat in the Survey**	**Run3 + Allow a dome to estimated in the fishery; Fixed at Age 5**
Model	No Split M = 0.3	No Split M = 0.3	No Split M = 0.3	No Split M = 0.3	No Split M = 0.3
Converge	Y	Y	N	Y	Y
S-R (Yes/No)	NO	NO	NO	NO	NO
Survey Selectivity	Survey Fixed Ages (NEFSC Fall = 3 , NEFSC SPR=2, MassFALL = 3 , MASS Spr = 2); All other ages estimated	Survey Fixed Ages (NEFSC Fall = 3 , NEFSC SPR=2, MassFALL = 3 , MASS Spr = 2); All other ages estimated	Survey Fixed Ages (NEFSC Fall = 3 , NEFSC SPR=3, MassFALL = 1 , MASS Spr = 2); All other ages estimated	Assumed Flattop Survey ; Fixed Ages (NEFSC Fall = 3+ , NEFSC SPR=2+, MassFALL = 3+ , MASS Spr = 2+); All other ages estimated	Survey Fixed Ages (NEFSC Fall = 3 , NEFSC SPR=2, MassFALL = 3 , MASS Spr = 2); All other ages estimated
Fishery Slectivity	Assume Flattop; Single Block Fishery Selectivity; Fixed at Age 4 and Older	**Assume Flattop; 2 blocks (1982-1998 and 1999-2010); fixed @ Age 5+ in Block 1 and Age 5+ in Block 2**	Assume Flattop; 2 blocks (1982-1998 and 1999-2010); fixed @ Age 3+ in Block 1 and Age 4+ in Block 2	Assume Flattop; 2 blocks (1982-1998 and 1999-2010); fixed @ Age 5+ in Block 1 and Age 5+ in Block 2	2 Blocks (1982-1998; 1999-2010, both fixed at age 5 and older)
Avg F	3-5	3-5	3-5	3-5	3-5
Objective Fxn	3480	3453	**3347**	3617	3352
Total Index_LL	1112	1120	1117	1174	**1098**
Index Age Comp_LL	1447	1447	**1329**	1588	1420
Total Catch_LL	142	142	142	154	**138**
Catch Age Comp_LL	428	397	416	325	**324**
NEFSC_q_fall	0.292	0.314	0.306	0.423	0.096
NEFSC_q_spr	0.167	0.179	0.235	0.247	0.055
Mass_q_fall	0.693	0.738	0.716	0.806	0.245
Mass_q_spr	0.923	0.982	0.928	1.145	0.326
Fleet 1 Sel	Flat Top	Flat Top	Flat Top	Flat Top	Dome
NEFSC_Fall_Surv_Sel	dome	dome	dome	Flat Top	Dome
NEFSC_Spr_Surv_Sel	dome	dome	dome	Flat Top	Dome
MASS_Fall_Surv_Sel	Stronger dome	Stronger dome	Stronger dome	Flat Top	Dome
MASS_Spr_Surv_Sel	Stronger dome	Stronger dome	Stronger dome	Flat Top	Dome
SSB (mt)	1,480-12,453	1,437-12,505	1,593-12,820	778-7,242	14,122-61,875
Rec (000's)	4,800-11,869	4,673-11,989	4,928-12,366	3,344-12,490	12,273-35,005
F	0.027-0.709	0.03-0.648	0.028-0.562	0.064-0.964	0.011-0.139
Retro_SSB (Rho)	19%	37%	**No Convergence**	110%	5%
Retro_Rec (Rho)	30%	37%	**No Convergence**	75%	28%
Retro_F (Rho)	-12%	-25%	**No Convergence**	-43%	-4%

Table C21. SDWG Pros and cons table for the final ASAP multi Gulf of Maine winter flounder assessment model
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Aspect of model	Pro	Con
Retrospective Patterns	Consistent F and SSB in last two years	Retrospective pattern before the last 2 years
Absolute Magnitude of Stock Biomass	Assessment 2010 biomass is greater [but not substantially greater] than the Survey based minimum area-swept biomass for 2010	
Survey Indices	In general, follows NEFSC and MADMF survey index trends	
Survey catchability (q)	Generally q < 1	Dome-shaped pattern in q at age
Fishery Catch	Model has flexibility to accommodate some degree of error in the catch at age	Significant residual error, particularly for age 8+ fish; requires constraint on fishery selectivity to provide feasible results
Stock Status	Current low F consistent with current low catch; recent trends and magnitude of catch and MSY estimate is consistent with the exploitation history	The assessment SSB time series is mostly >Bmsy, inferring that the stock has rarely experienced overfishing. Assessment results indicate that current SSB is at about 2/3 of unfished SSB. However, current fishery and survey evidence suggest fish are not abundant in historical inshore habitats
Stock-Recruitment Model	Provides FMSY	Poorly defined relationship

Table C22. Non-parametric empirical (F30, F35, F40) and stock recruit based (Fmsy) biological reference points and stock status (SSB2010/SSBmsy and F2010/Fmsy ratios) for Gulf of Maine winter flounder from the split VPA, ASAP indices at age, and ASAP multi run models. Projected long term SSBmsy and MSY reference point equivalents for parametric based reference points are given in parentheses.

	Split VPA	Indices at Age ASAP Base	ASAP Multi	ASAP Multi with h-prior
F_{30}	0.68	0.44	0.51	-
F_{35}	0.54	0.36	0.42	-
F_{40}	0.43	0.30	0.34	-
F_{MSY}	0.40	0.49	0.66	0.57
Steepness	0.66	0.85	0.88	0.84
F_{max}	N/A	1.43	1.63	-
Mean Recruits (000s)	5,687	10,209	8,148	8,148
MSY (mt) F30	780	1,470	1,191	-
MSY (mt) F35	752	1,403	1,139	-
MSY (mt) F40	720	1,329	1,080	-
MSY (mt) Fmsy	942	1,405	1,158 (1181)	1,128 (1152)
SSB_{MSY} (mt) F30	1,691	3,290	2,464	-
SSB_{MSY} (mt) F35	1,989	3,837	2,874	-
SSB_{MSY} (mt) F40	2,292	4,388	3,287	-
SSB_{MSY} (mt) Fmsy	3,193	2,796	1,876 (1913)	2,121 (2167)
SSB_{10} (mt)	1,667	8,464	5,803	5,803
F_{10}	0.19	0.02	0.03	0.03
SSB_{10}/SSB_{MSY} F30	0.99	2.57	2.36	-
SSB_{10}/SSB_{MSY} F35	0.84	2.21	2.02	-
SSB_{10}/SSB_{MSY} F40	0.73	1.93	1.77	-
SSB_{10}/SSB_{MSY} Fmsy	0.52	3.03	3.09 (3.03)	2.74 (2.68)
F_{10}/F_{MSY} F30	0.28	0.05	0.06	-
F_{10}/F_{MSY} F35	0.35	0.06	0.08	-
F_{10}/F_{MSY} F40	0.44	0.07	0.09	-
F_{10}/F_{MSY} Fmsy	0.47	0.04	0.05	0.06

Table C23. Yield per recruit input from the ASAP multi run.

age	ASAP Multi selectivity	proportion mature	avg catch weight	avg stock weight
1	0.013	0.000	0.042	0.025
2	0.054	0.040	0.142	0.079
3	0.261	0.350	0.362	0.243
4	0.885	0.880	0.474	0.422
5	1.000	0.990	0.595	0.540
6	1.000	1.000	0.716	0.670
7	1.000	1.000	0.975	0.975

Table C24. Likelihood profile on steepness for the split VPA and the ASAP indices at age run.

		Split VPA		
AIC	steepness	MSY	Fmsy	SSBmsy
128.65	0.55	1,332	0.29	6,062
126.87	0.60	1,088	0.34	4,299
126.24	0.65	964	0.39	3,378
126.38	0.70	893	0.45	2,742
126.99	0.75	851	0.53	2,298
127.88	0.80	827	0.63	1,937
128.92	0.85	815	0.76	1,634

	ASAP Indices at Age			
AIC	steepness	MSY	Fmsy	SSBmsy
137.40	0.65	1,304	0.28	4,563
134.36	0.70	1,318	0.32	4,032
132.40	0.75	1,341	0.37	3,591
131.36	0.80	1,371	0.43	3,148
131.08	0.85	1,408	0.50	2,745
131.38	0.90	1,455	0.61	2,340
132.09	0.95	1,517	0.80	1,855

Table C25. Example of a possible plus group residual adjustment within AGEPRO as assumed plus group discards from the ASAP Indices at age run.

Plus group residual considerations	ASAP
F_{40}	0.30
MSY (mt) F40	1,329
MSY (mt) 25% plusgroup	1,279
MSY (mt) 50% plusgroup	1,228
MSY (mt) 75% plusgroup	1,178
25% 8+ never seen	50
50% 8+ never seen	101
75% 8+ never seen	151
SSB_{MSY} (mt) F40	4,388

C. GOM Winter Flounder Figures

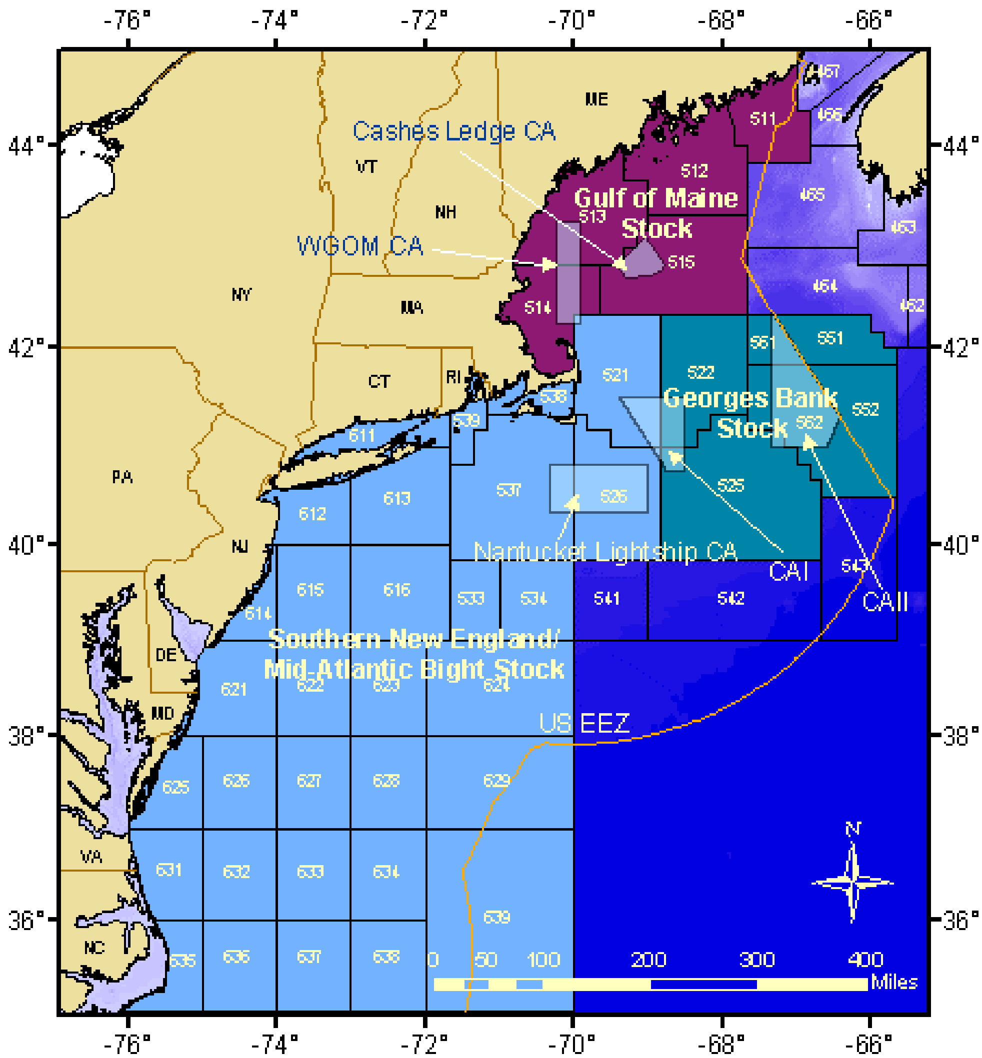


Figure C1. Statistical areas used to define winter flounder stocks. The Gulf of Maine stock includes area 511-515.

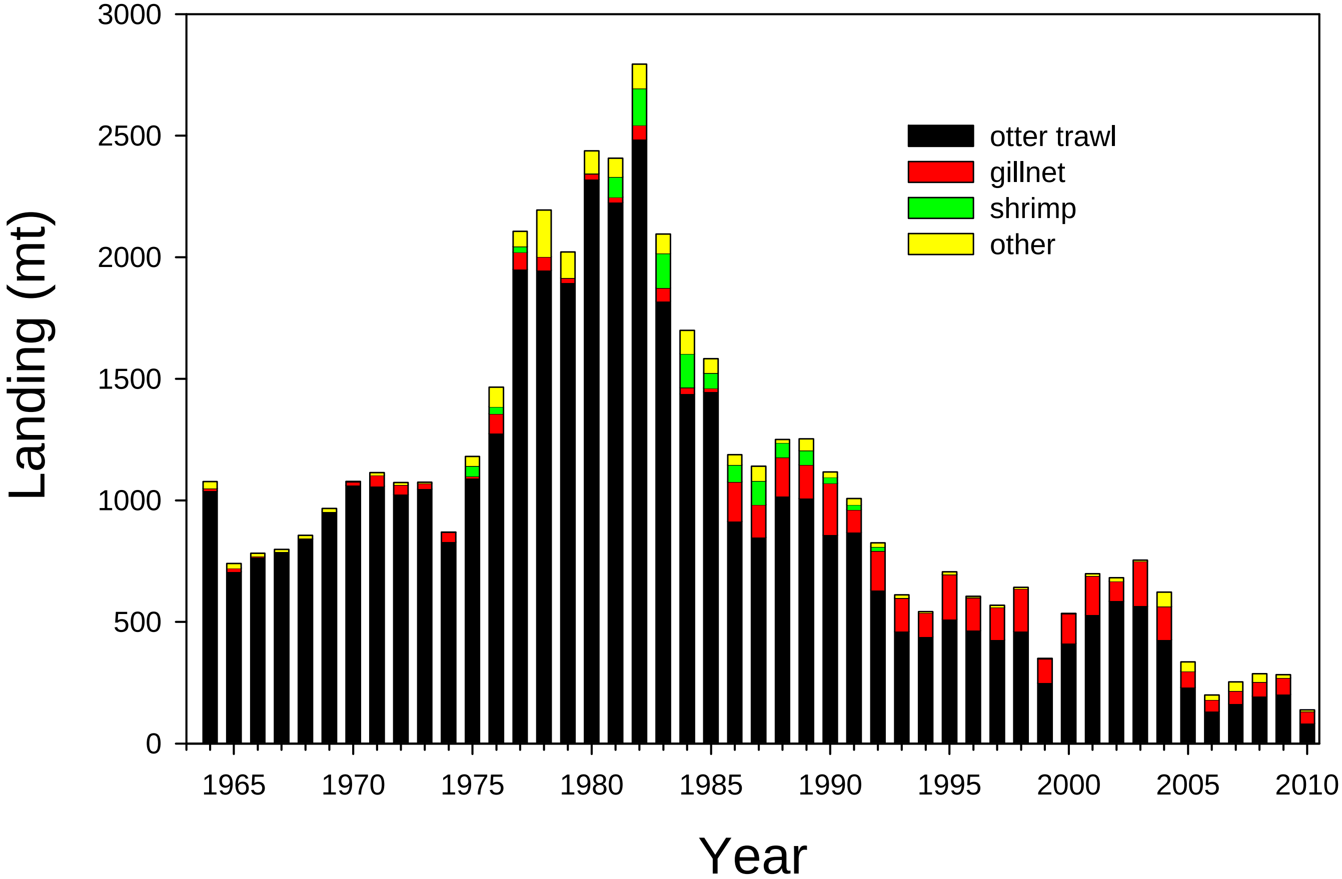


Figure C2. Commercial landings by gear 1964-2010.

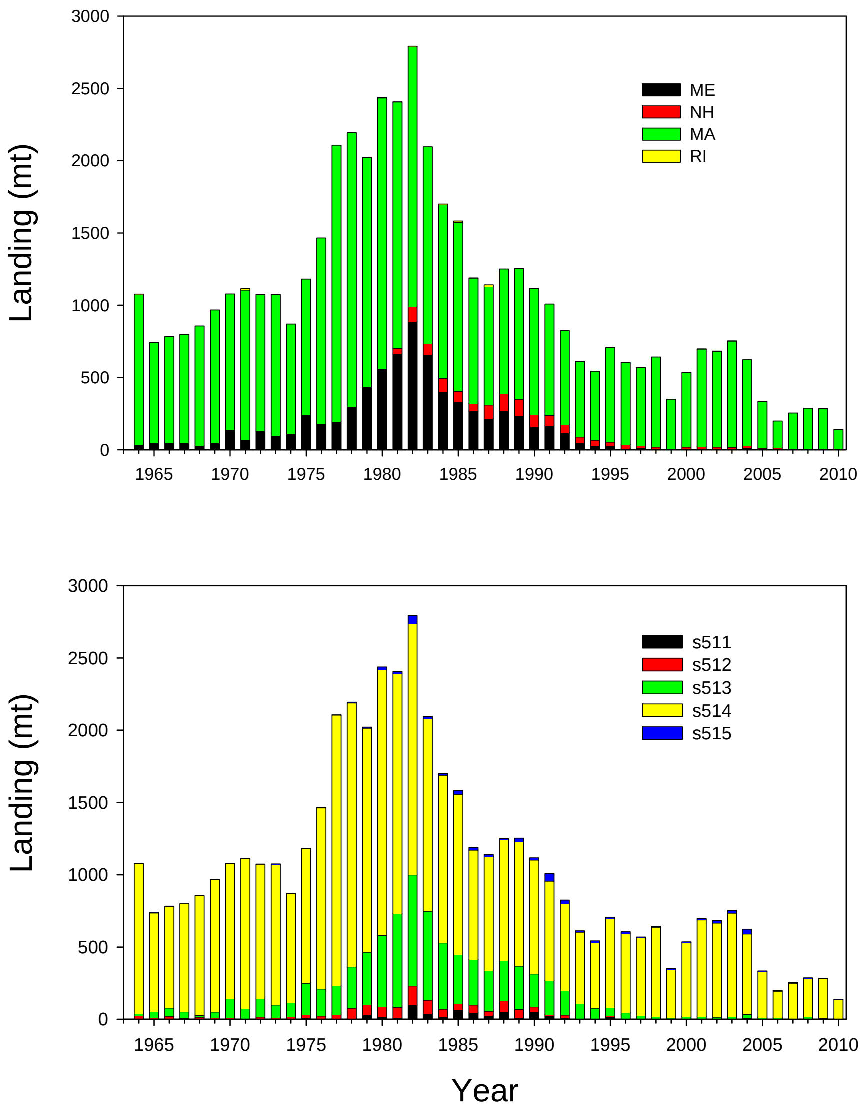
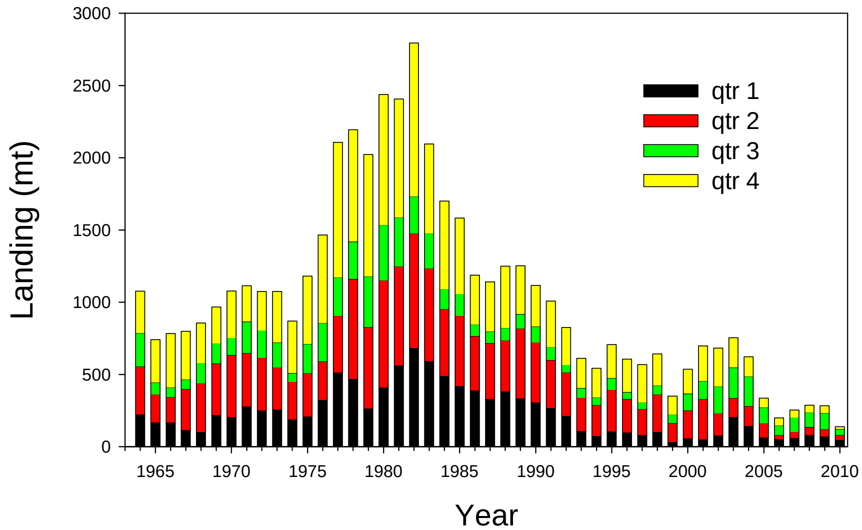


Figure C3. Commercial landings by state (top) and statistical area (bottom) 1964-2010.



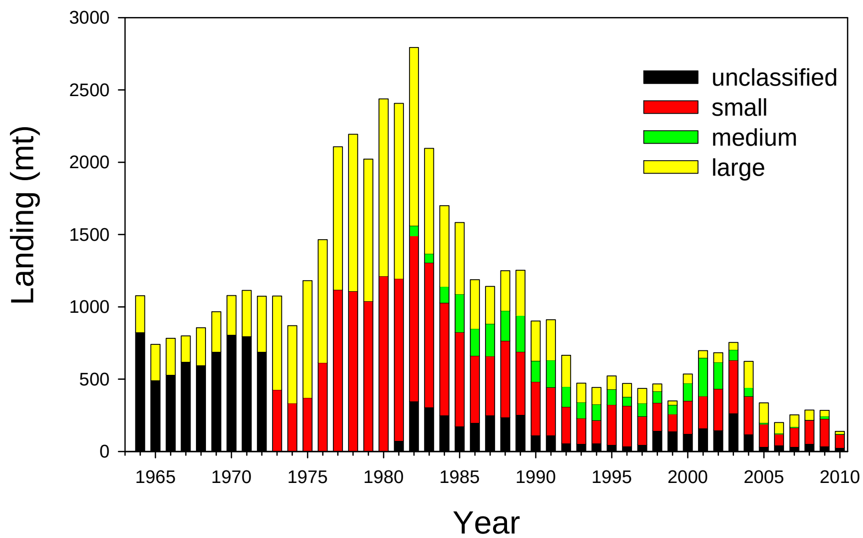


Figure C4. Commercial landings by quarter (top) and market category (bottom) 1964-2010.

Gulf of Maine Winter Flounder Recreational landings and b2 Catch

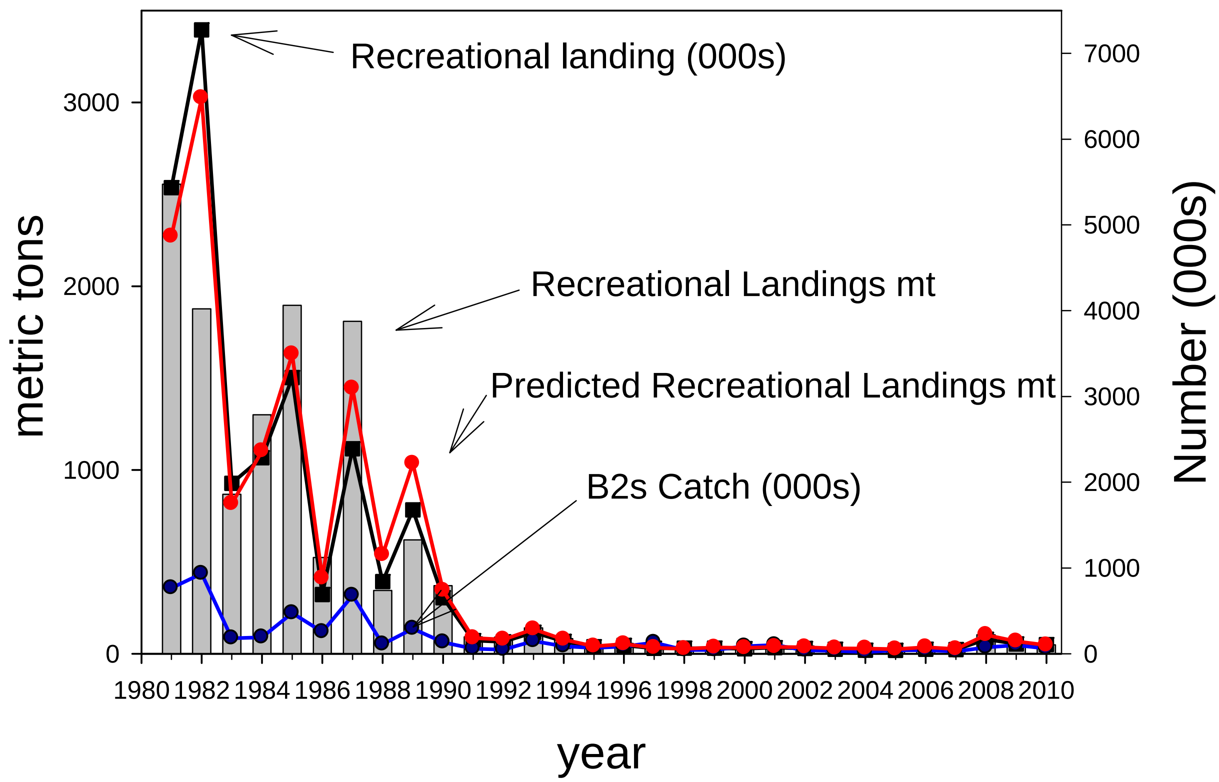


Figure C5 Recreational landings in numbers and metric tons for Gulf of Maine winter flounder. B2 catch in numbers is also shown.

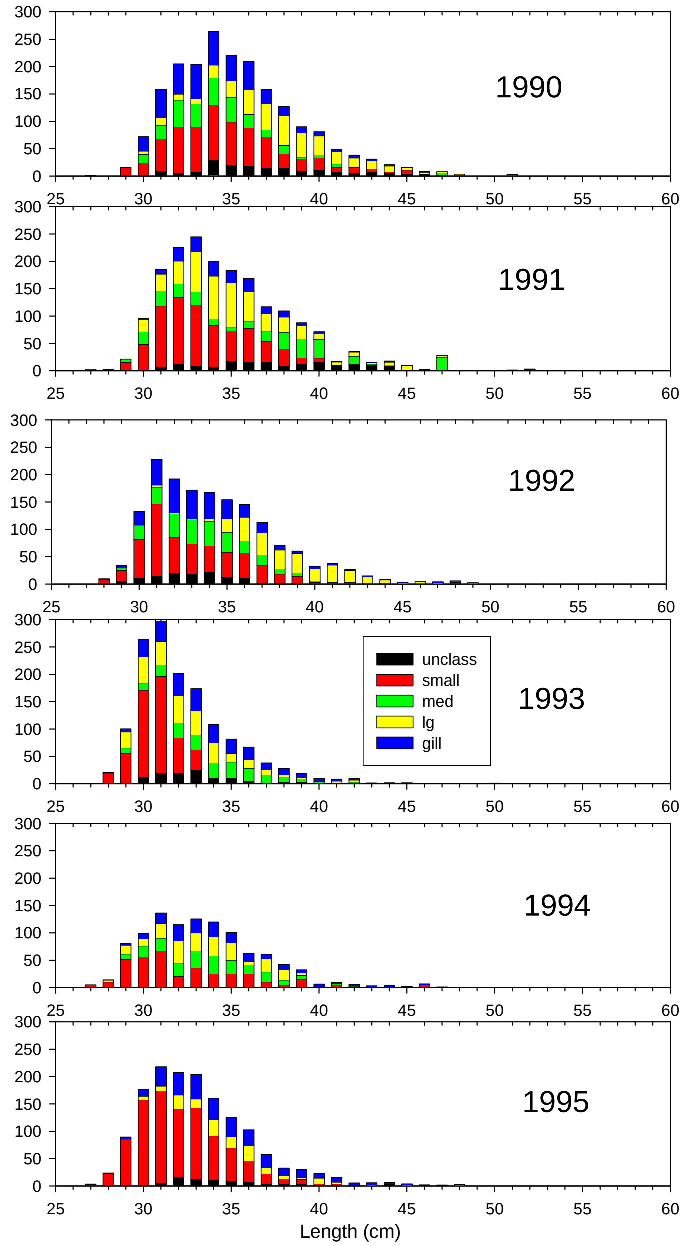


Figure C6. Expanded landing length distribution using port sampling data.

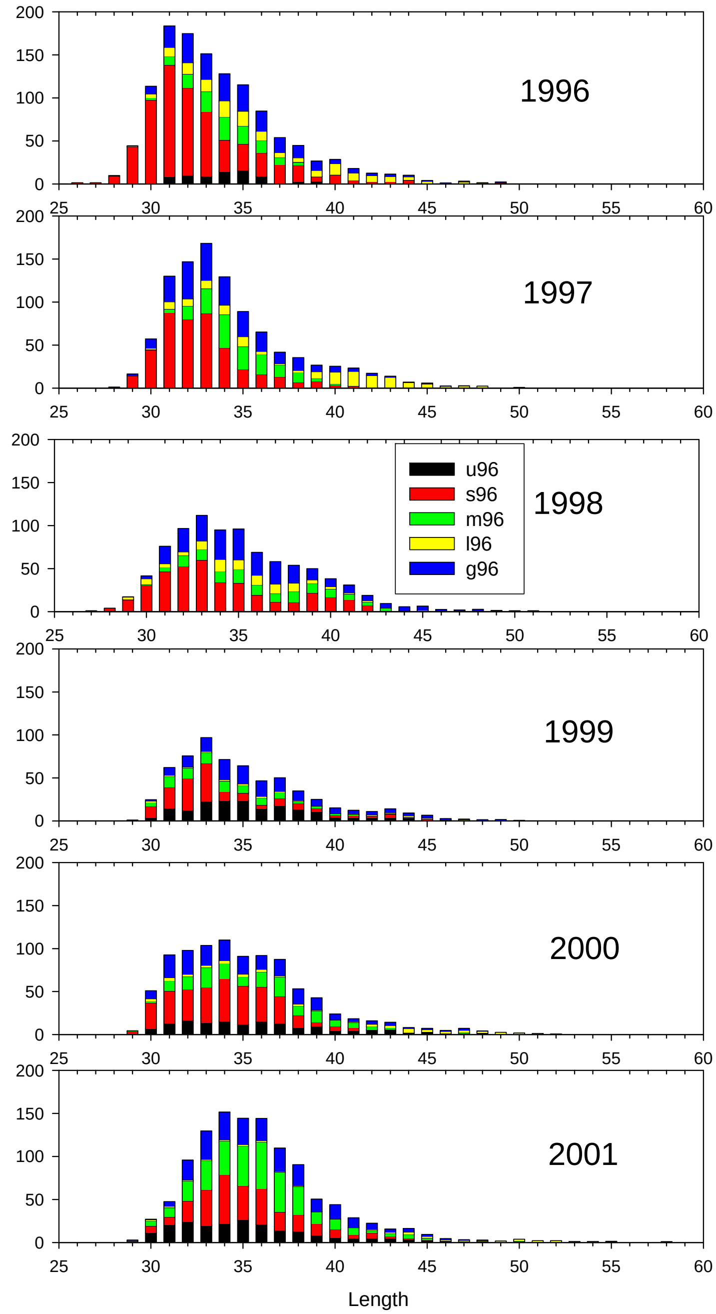


Figure C6. Cont.

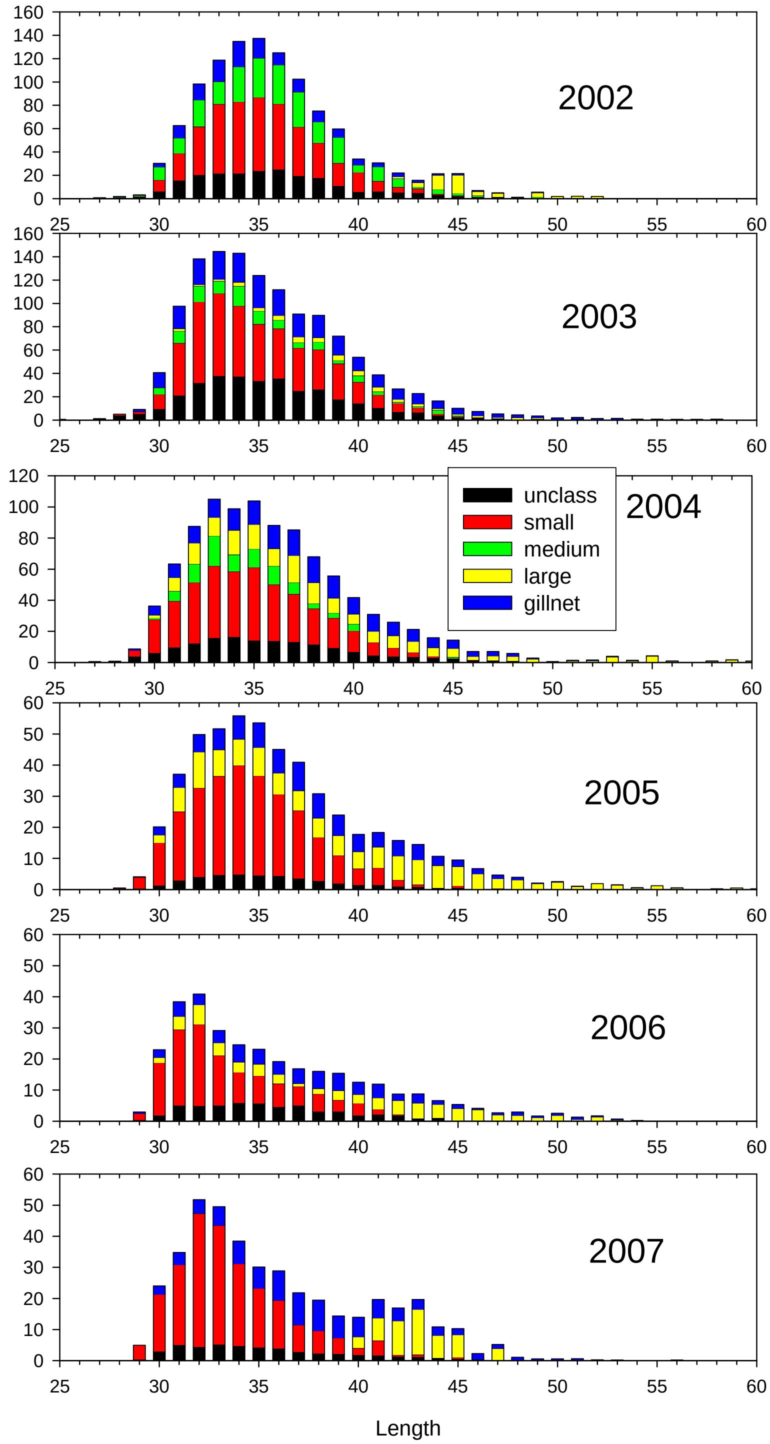


Figure C6. Cont.

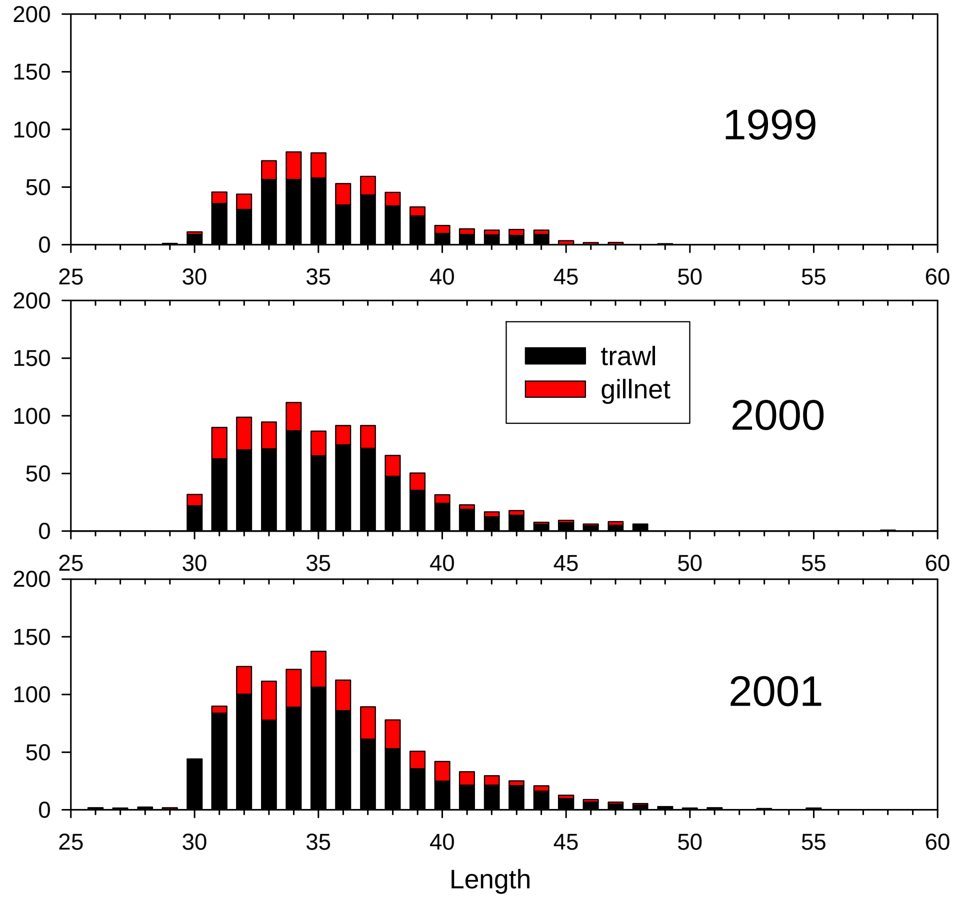
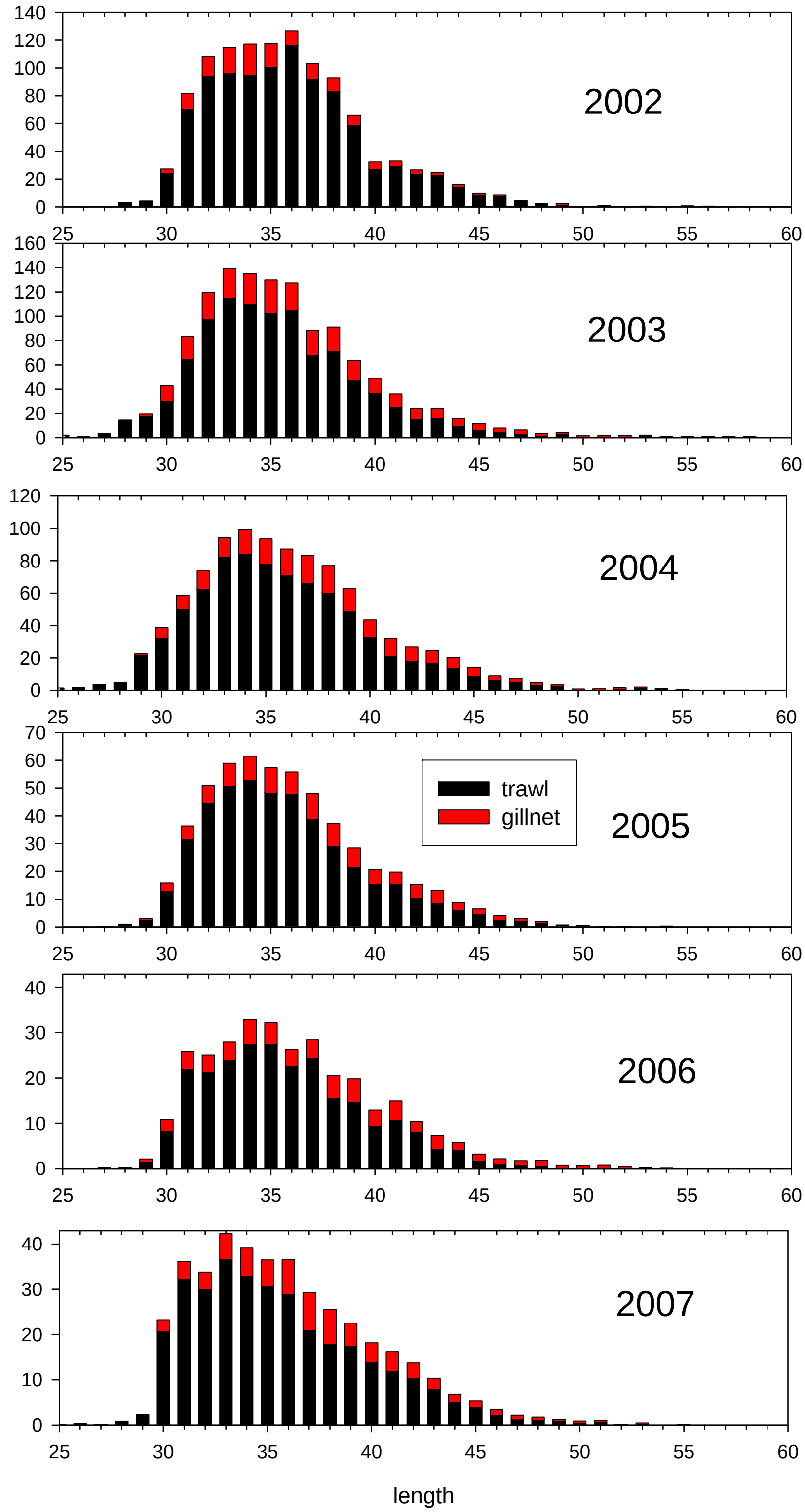


Figure C7. Expanded landing length distribution using observer data.



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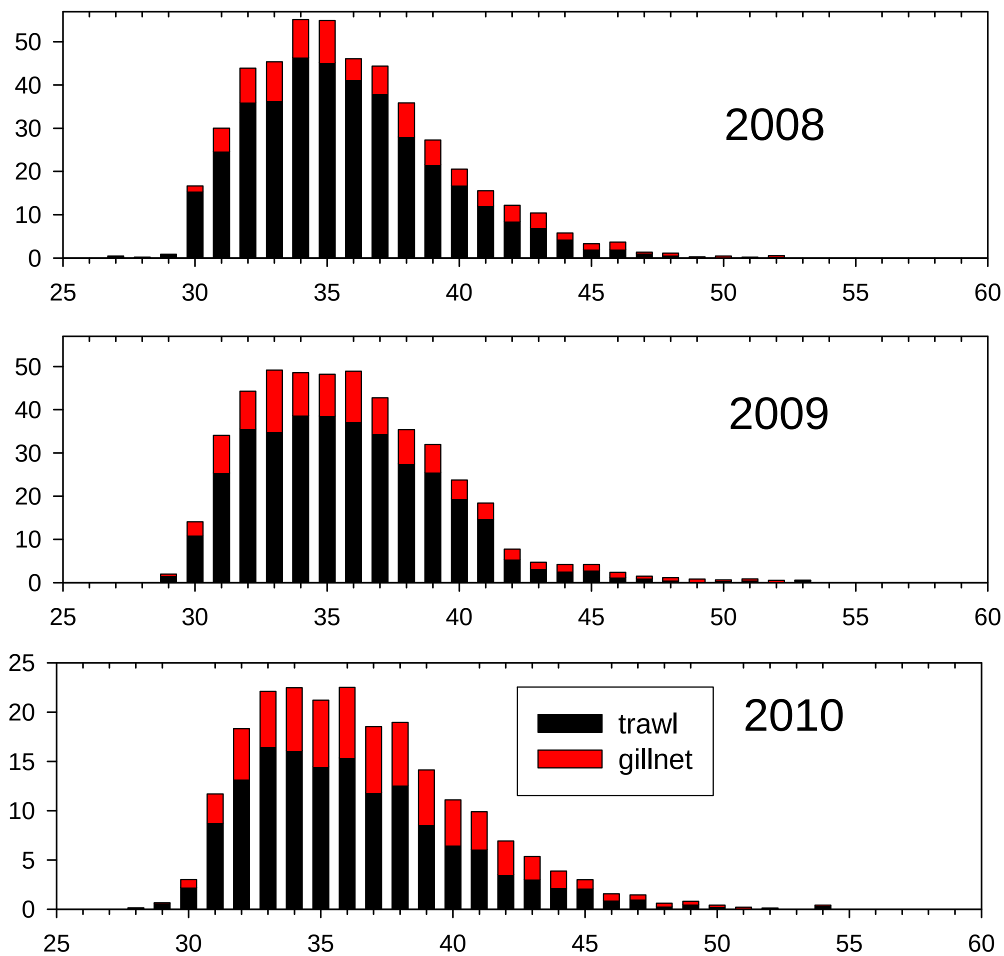
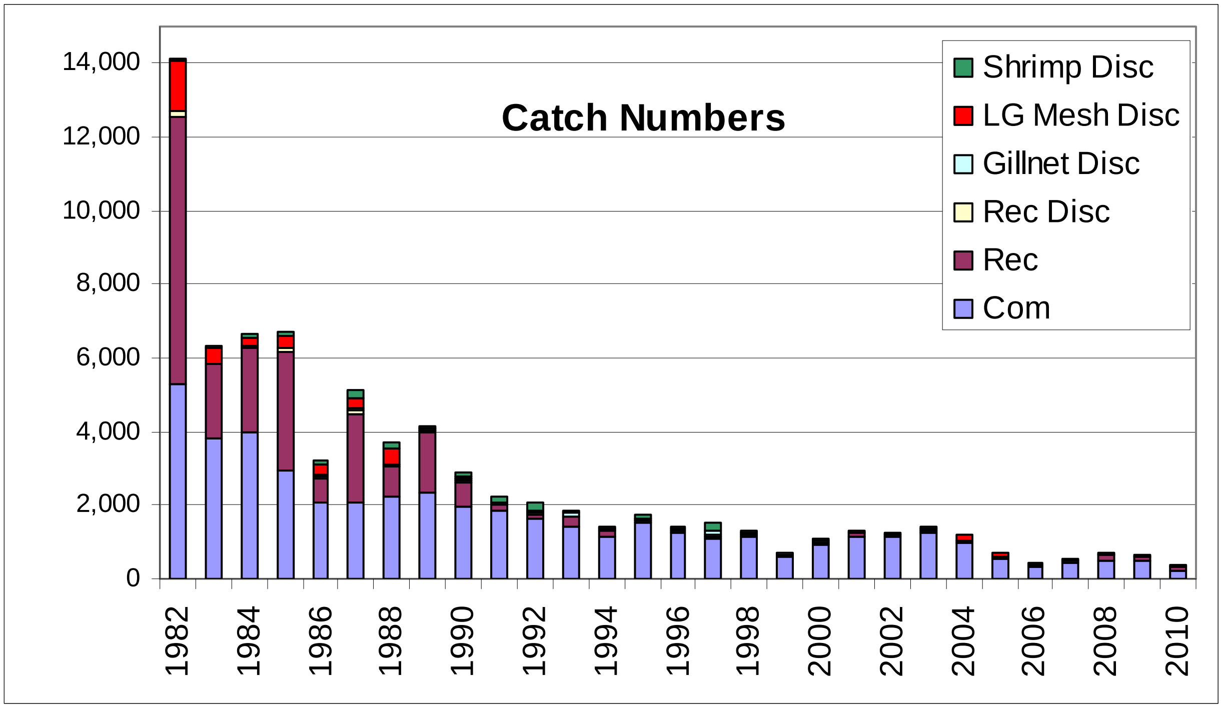


Figure C7. Cont.



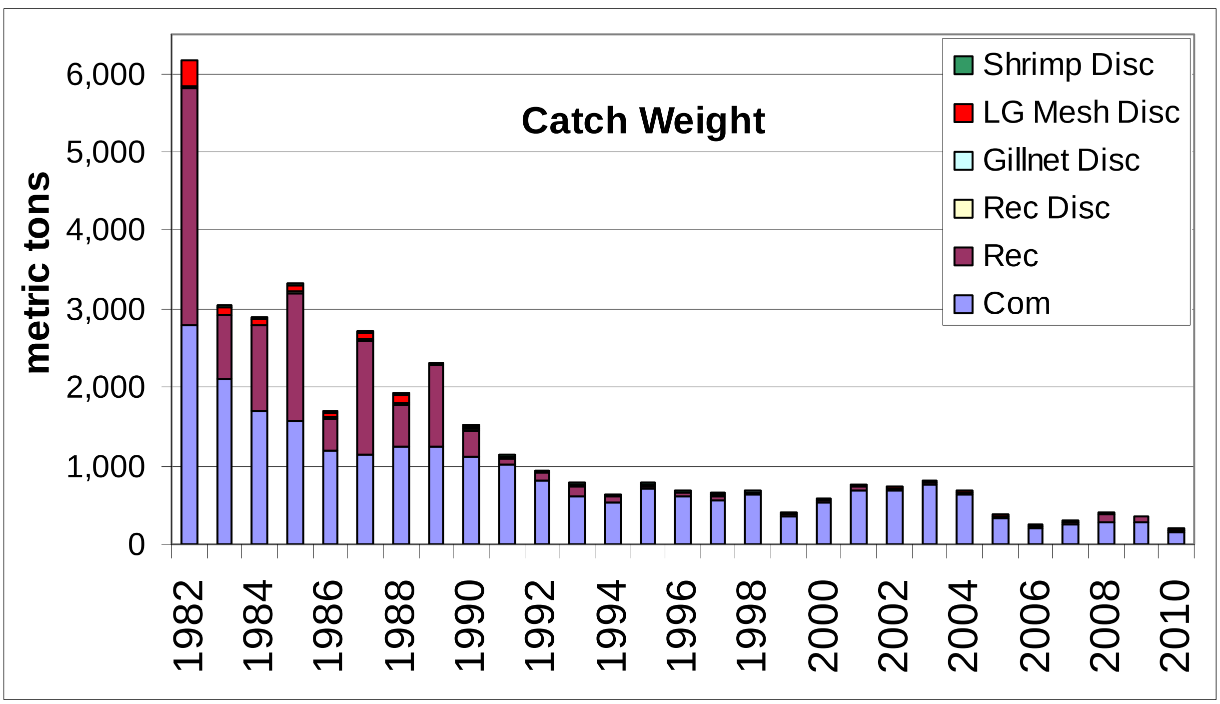


Figure C8. Gulf of Maine winter flounder composition of the catch by numbers and weight.

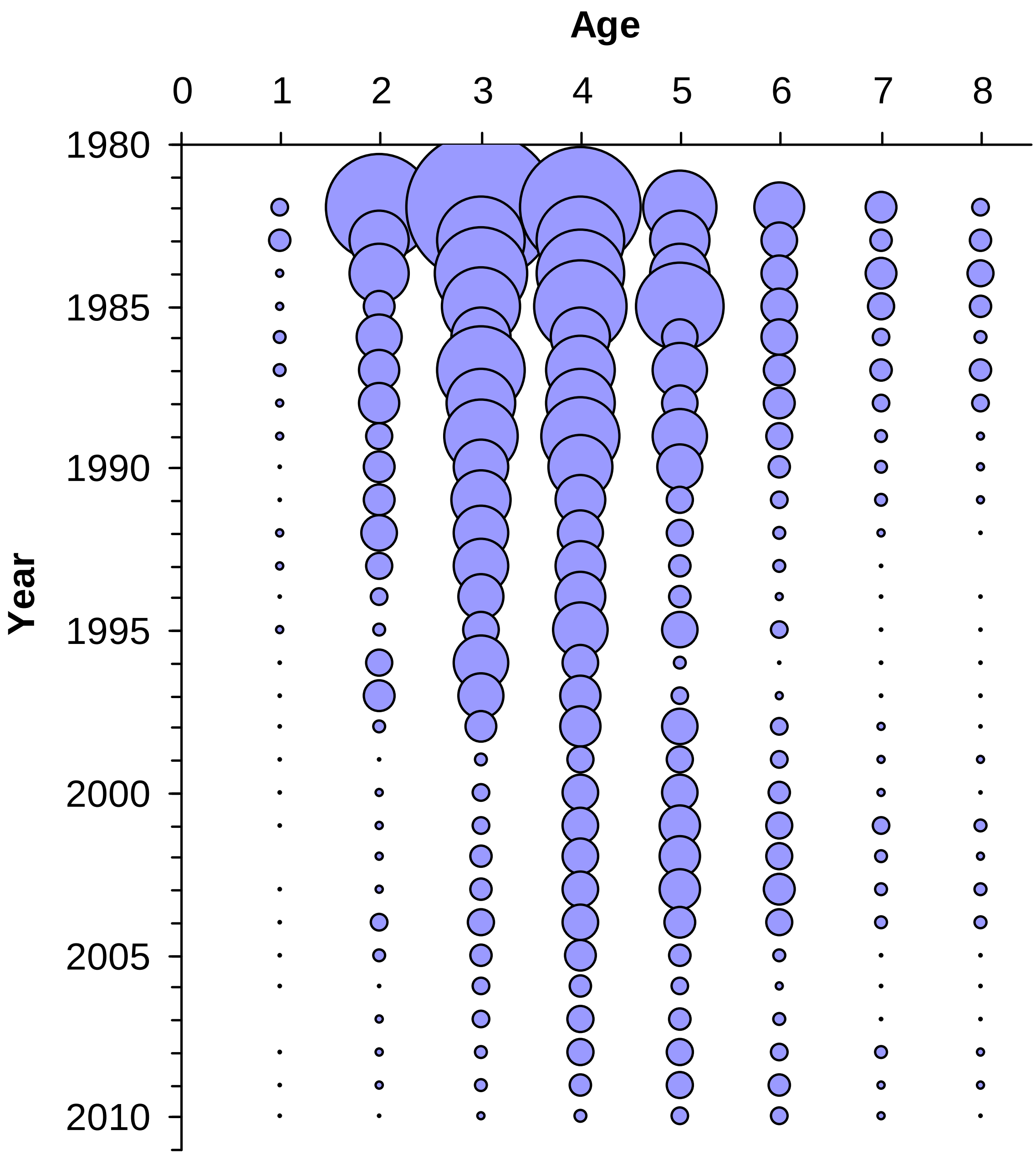


Figure C9. Gulf of Maine winter flounder bubble plot of the catch at age.

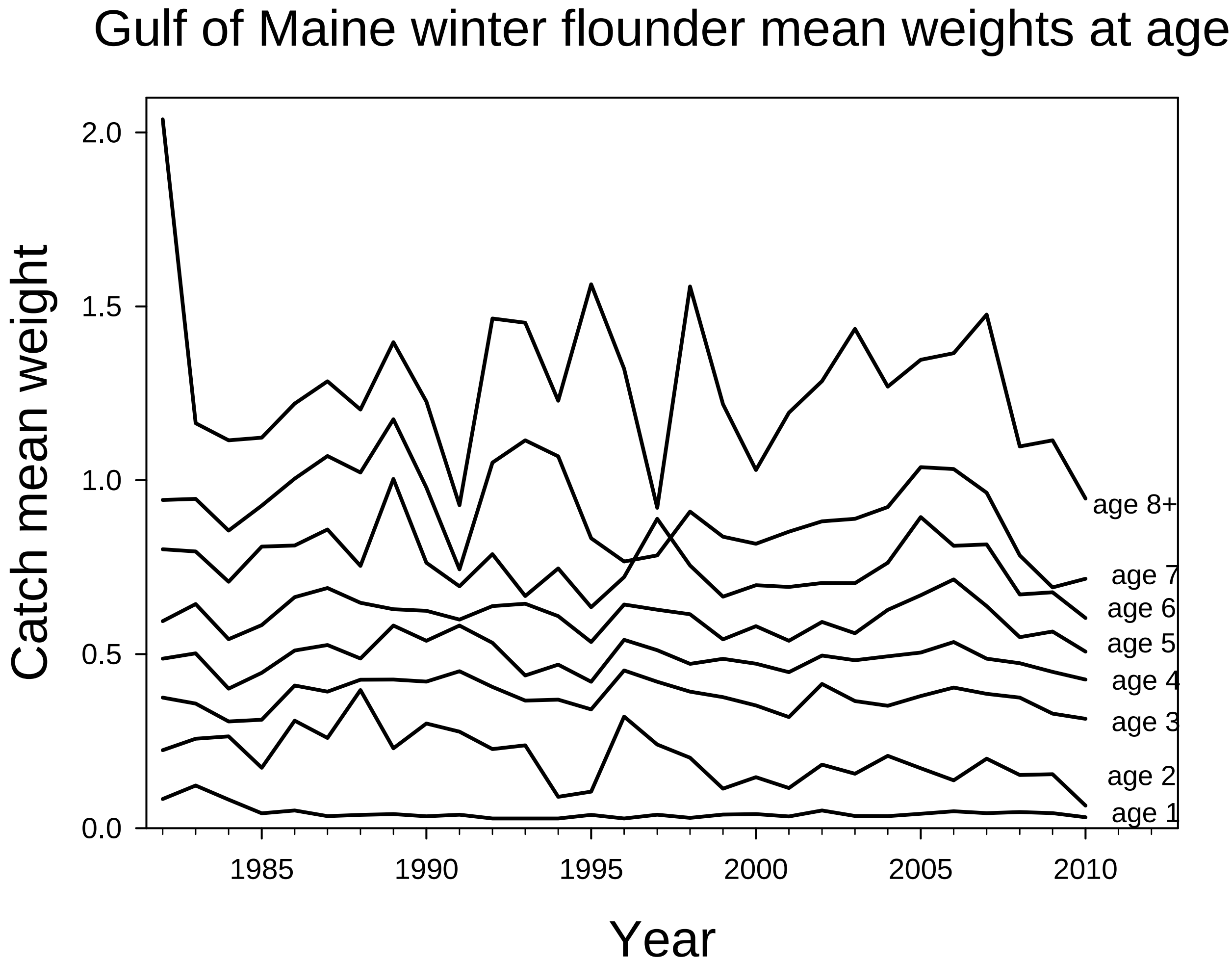


Figure C10. Gulf of Maine winter flounder mean catch weights at age (kg).

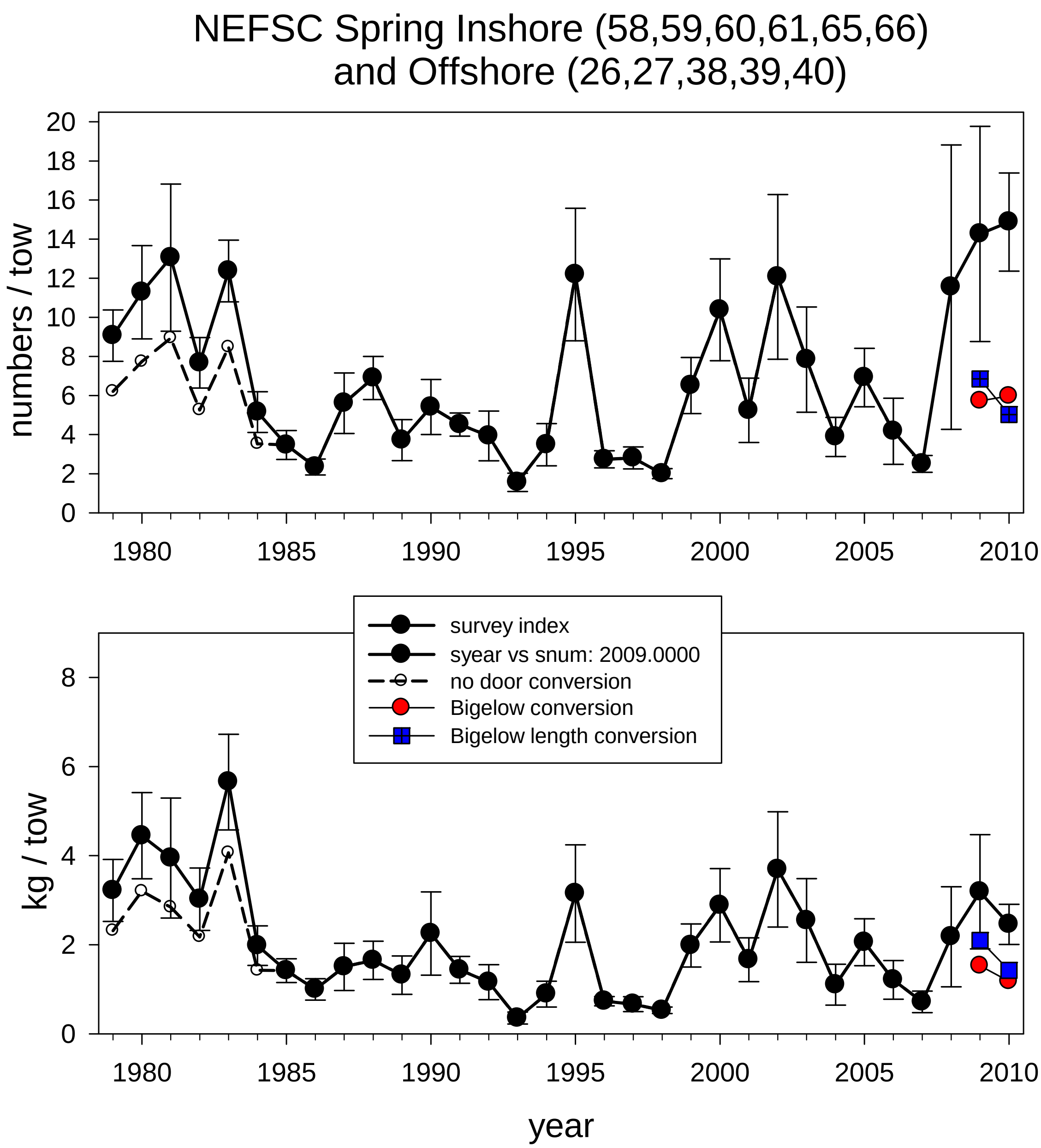


Figure C11. NEFSC spring survey stratified mean numbers and mean weight (kg) per tow for Gulf of Maine winter flounder. Trawl door conversion factors are use where appropriate. Dotted lines are unconverted door indices. Bigelow aggregate (red dots) and length based conversion (blue squares) are also shown.

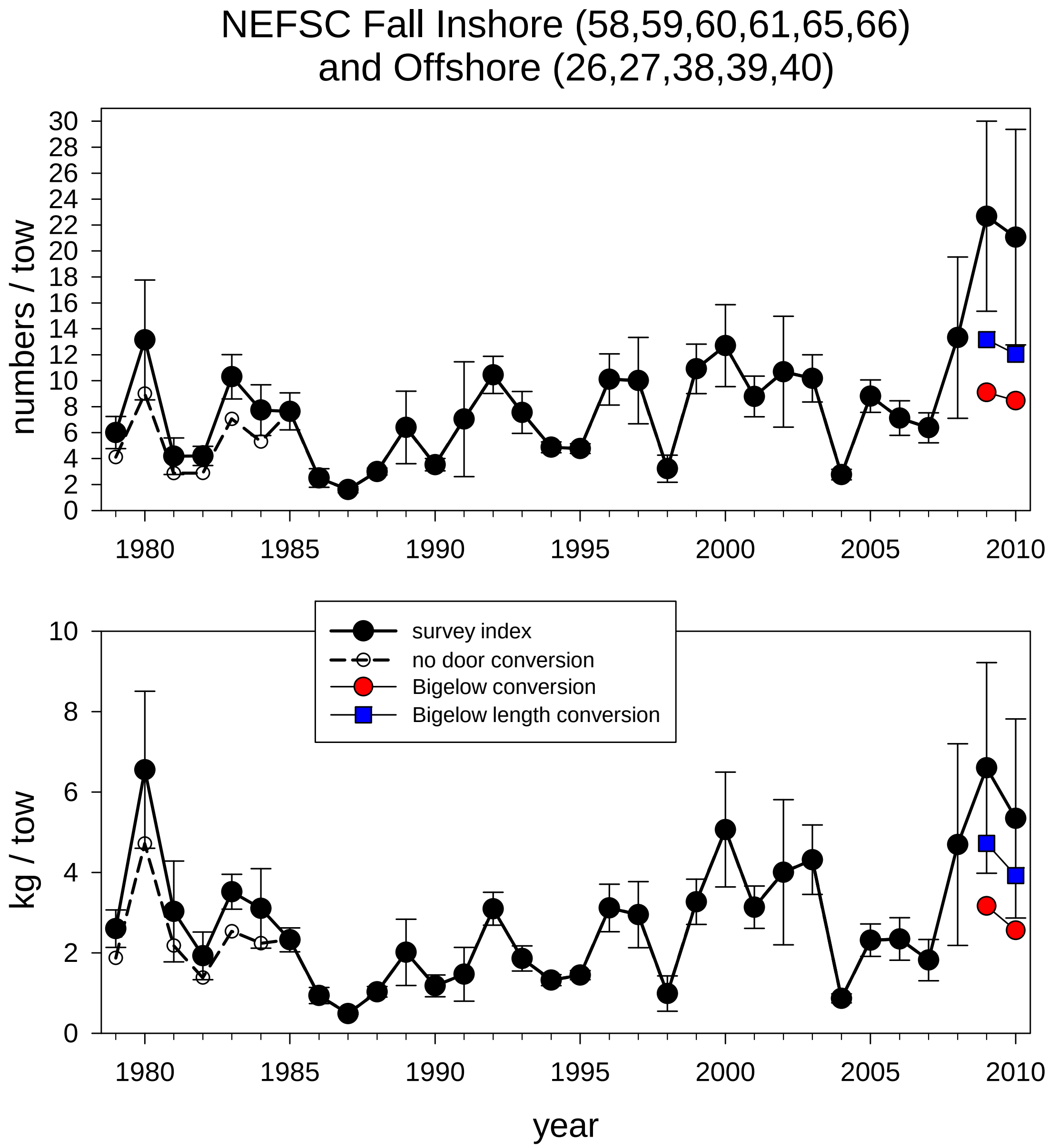


Figure C12 NEFSC fall survey stratified mean numbers and mean weight (kg) per tow for Gulf of Maine winter flounder. Trawl door conversion factors are use where appropriate. Dotted lines are unconverted door indices. Bigelow aggregate (red dots) and length based conversion (blue squares) are also shown. The 2010 index did not have Cape Cod Bay strata sampled.

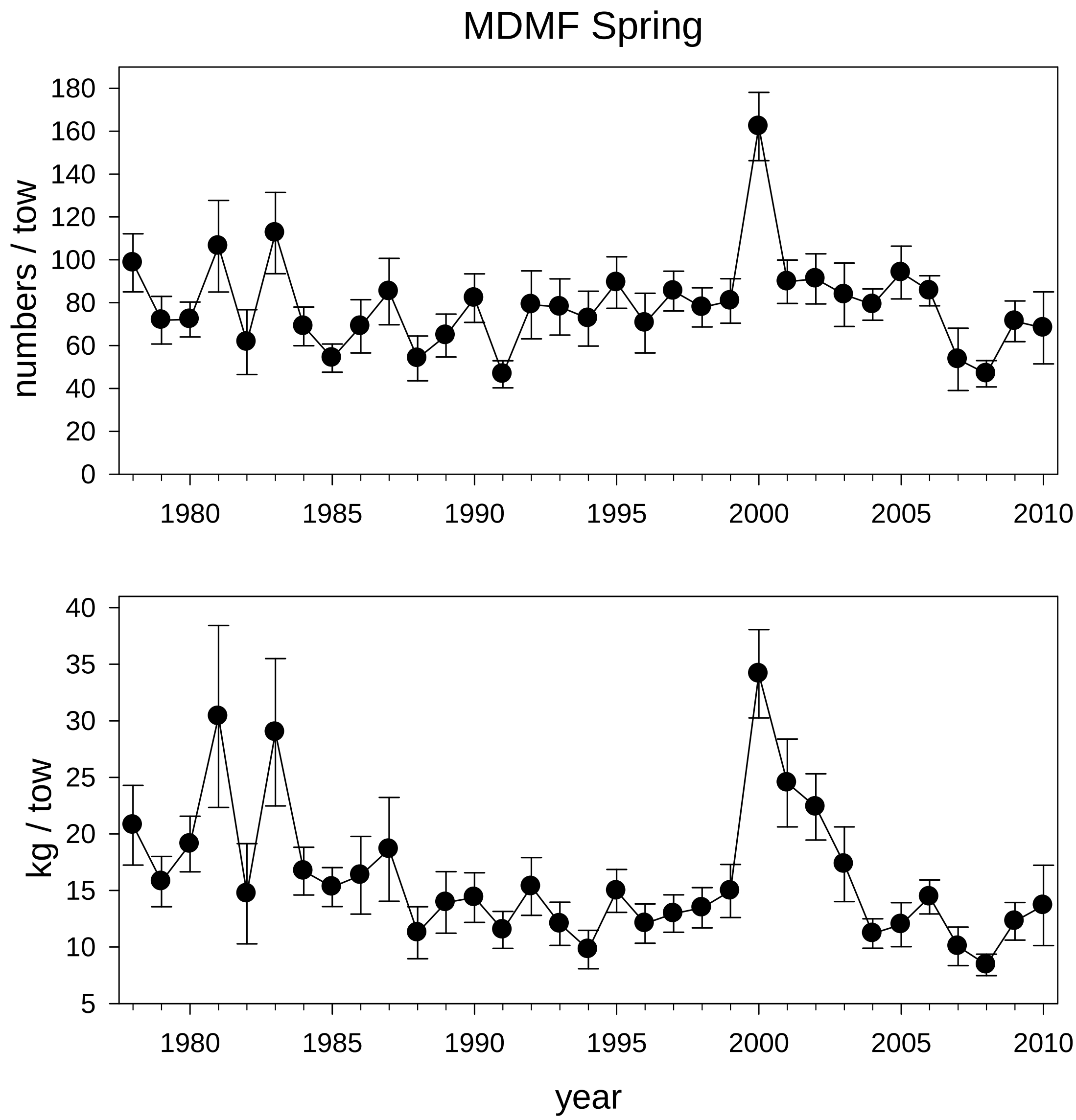


Figure C13. Massachusetts Division of Marine Fisheries (MDMF) spring survey stratified mean numbers and mean weight (kg) per tow for Gulf of Maine winter flounder.

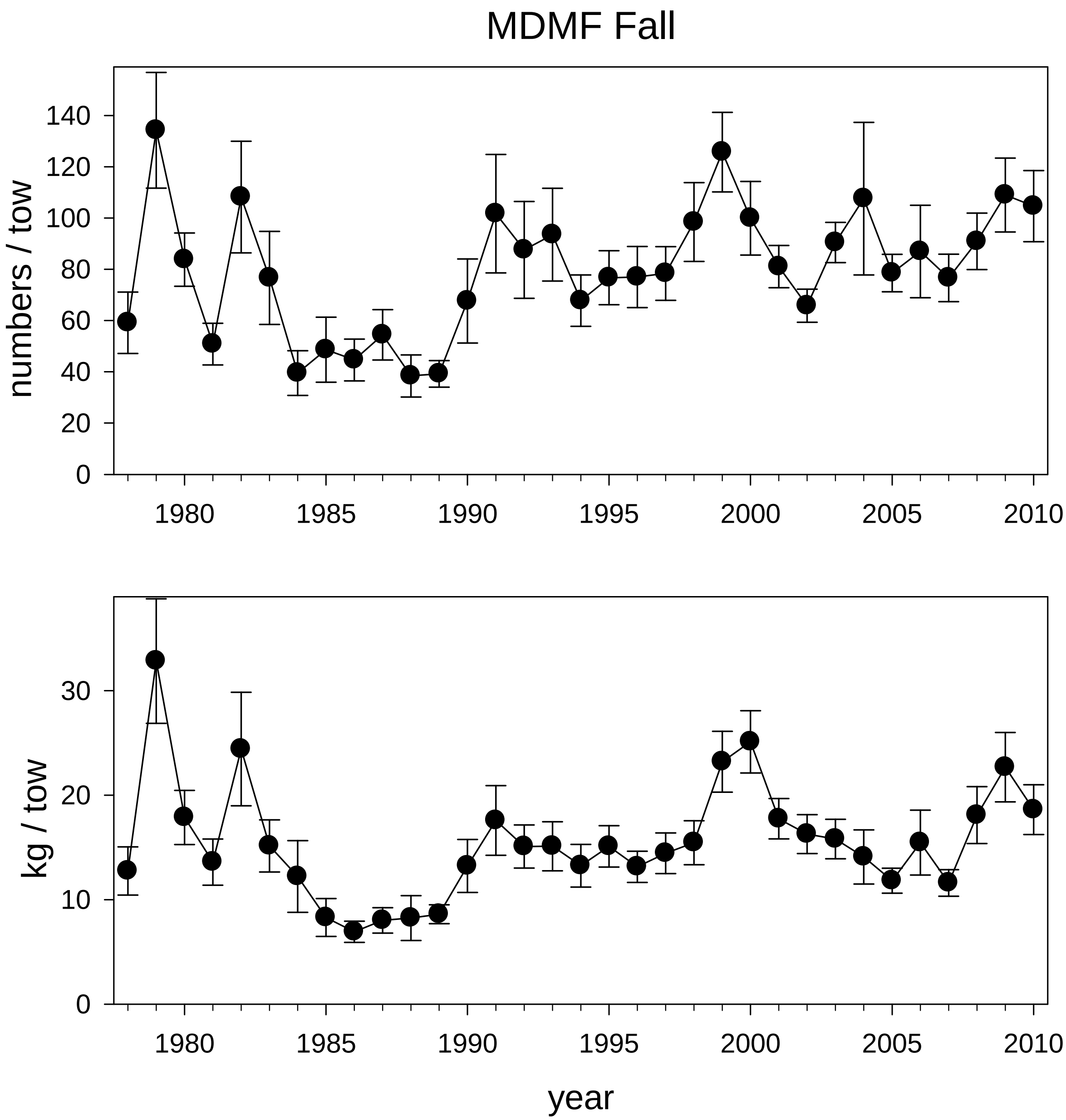


Figure C14. Massachusetts Division of Marine Fisheries (MDMF) fall survey stratified mean numbers and mean weight (kg) per tow for Gulf of Maine winter flounder.

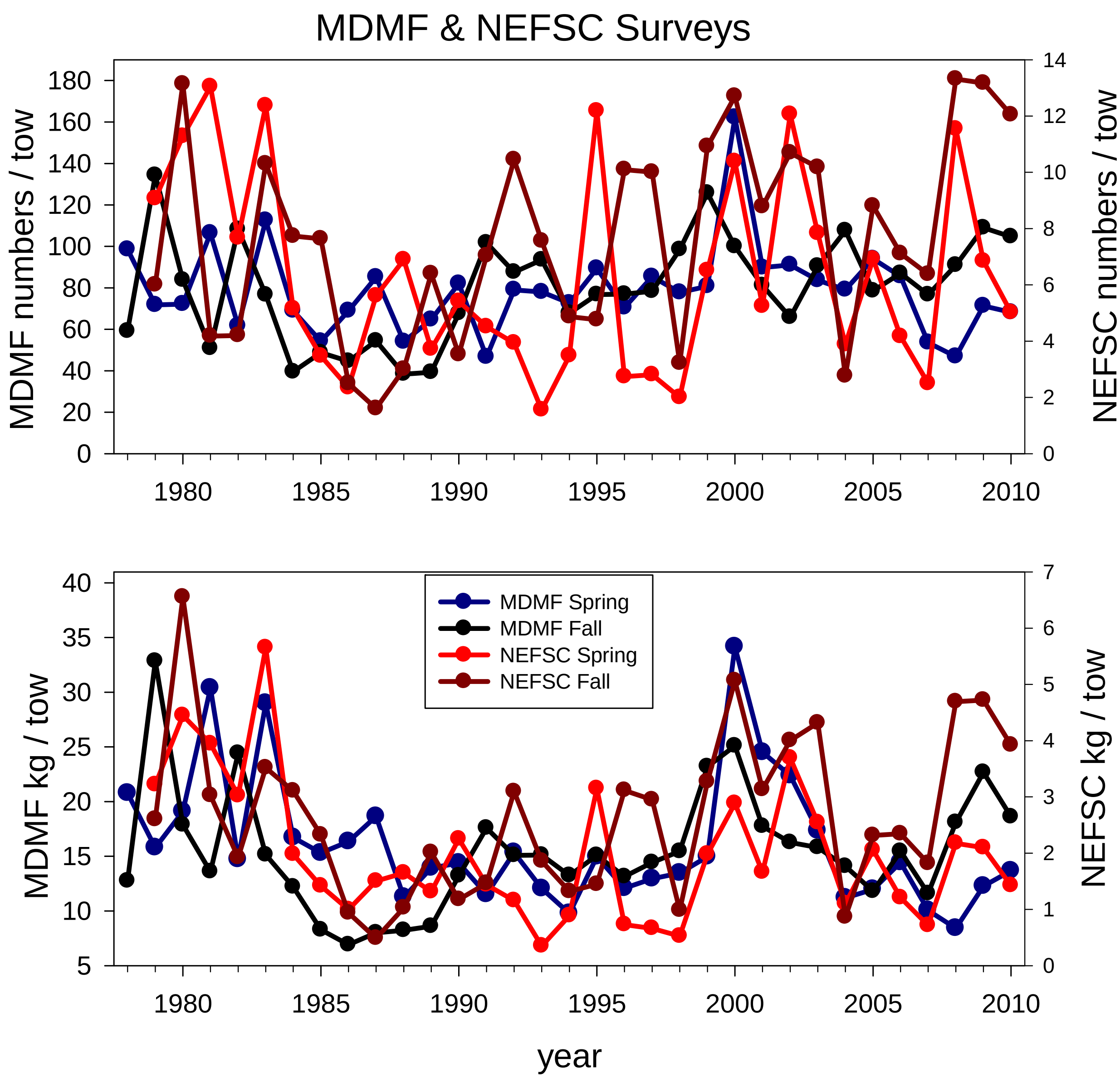


Figure C15. All four survey stratified mean numbers and mean weight (kg) per tow trends for Gulf of Maine winter flounder.

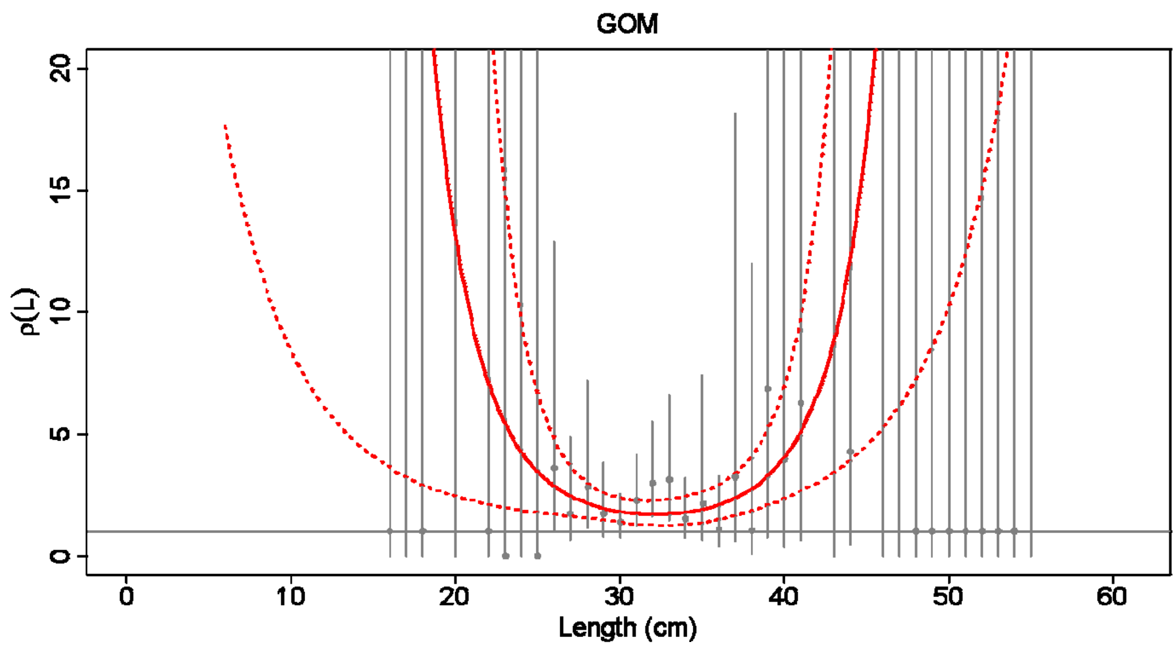


Figure C16. Estimated Length based calibration coefficients for Gulf of Maine winter flounder.

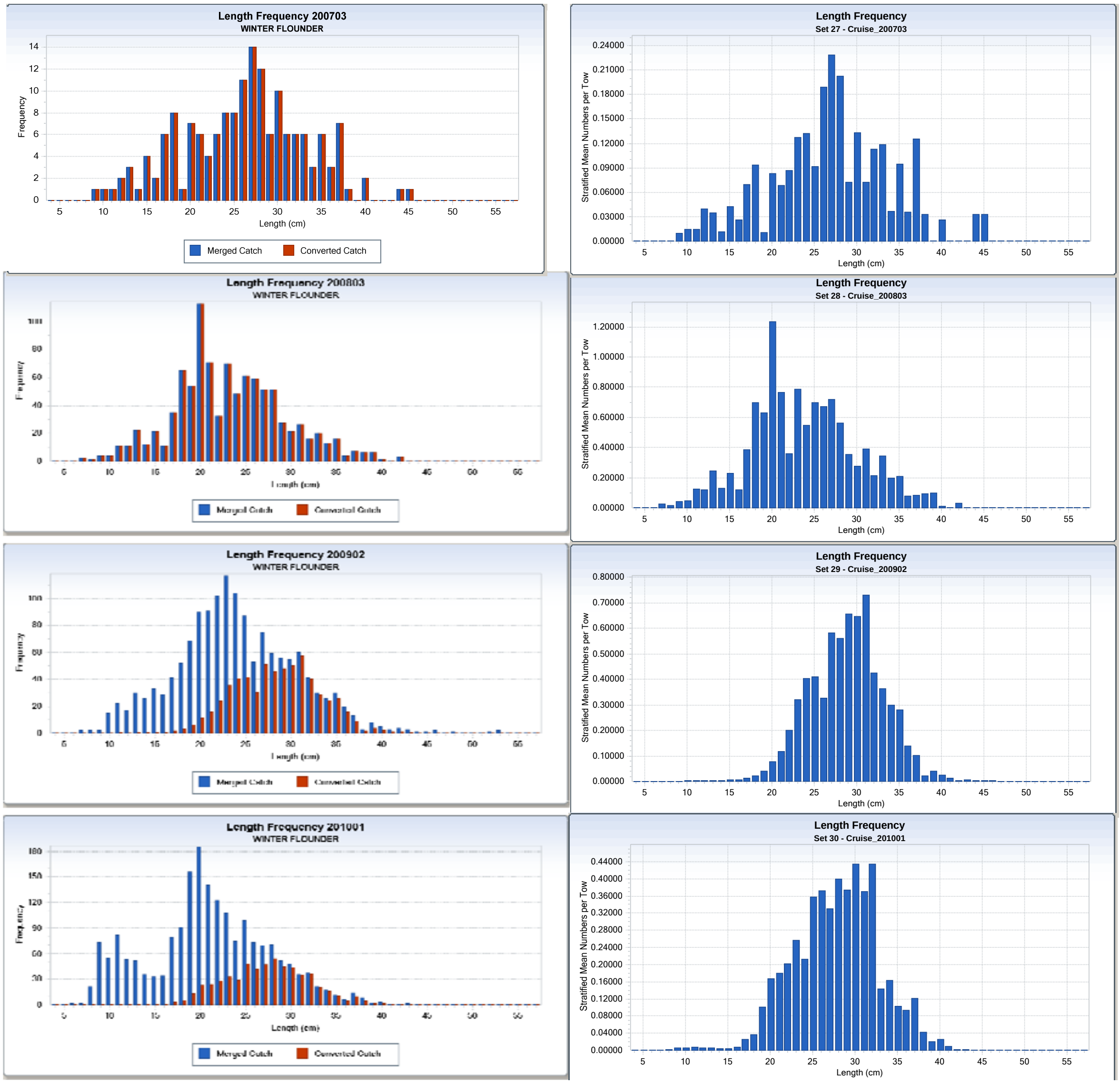


Figure C17. Spring raw and converted survey length distributions in 2009 and 2010. Albatross distributions are shown for 2008 and 2009 for comparison. Stratified converted length distributions are shown on the right.

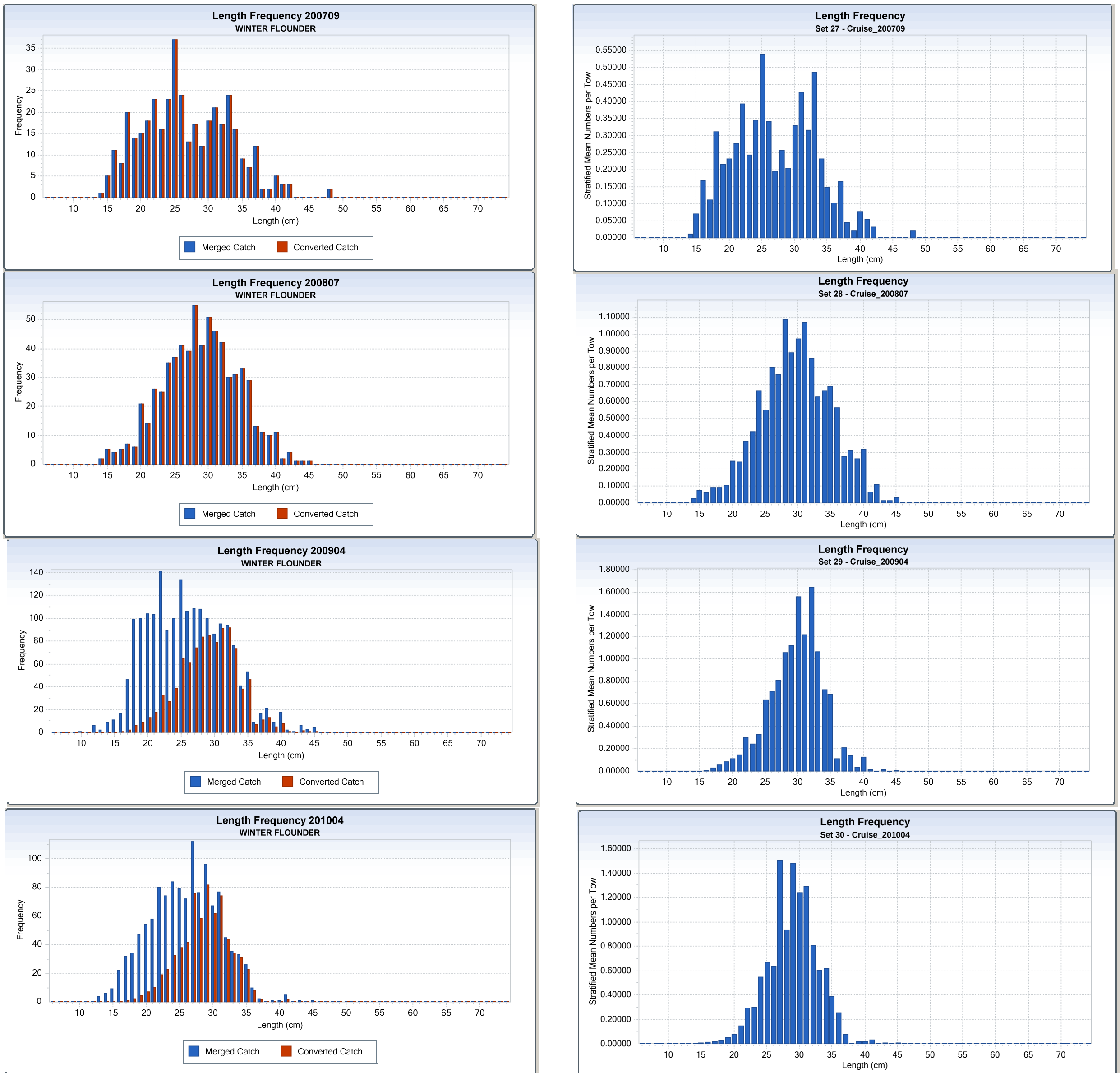
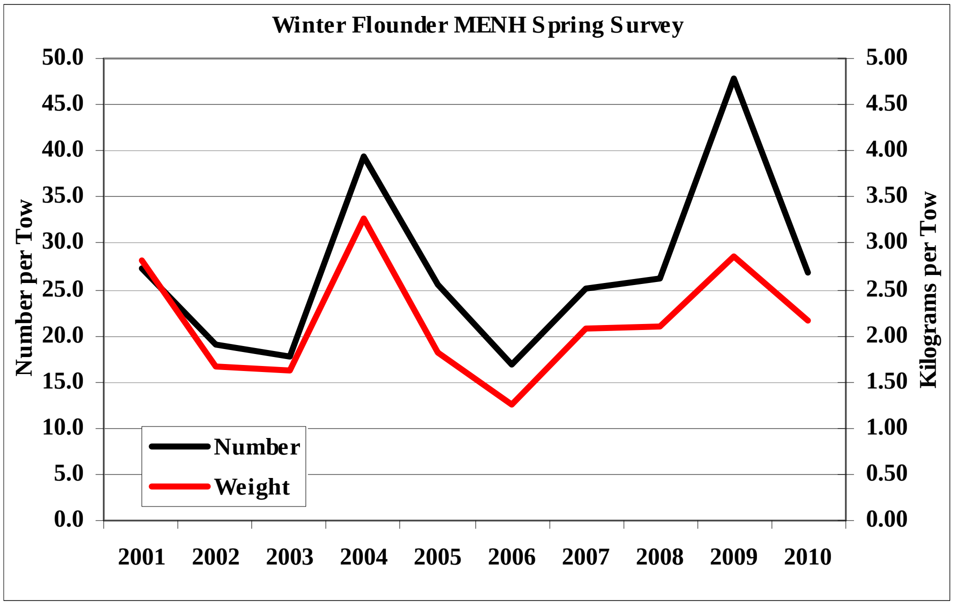


Figure C18. Fall raw and converted survey length distributions in 2009 and 2010. Albatross distributions are shown for 2008 and 2009 for comparison. Stratified converted length distributions are shown on the right.



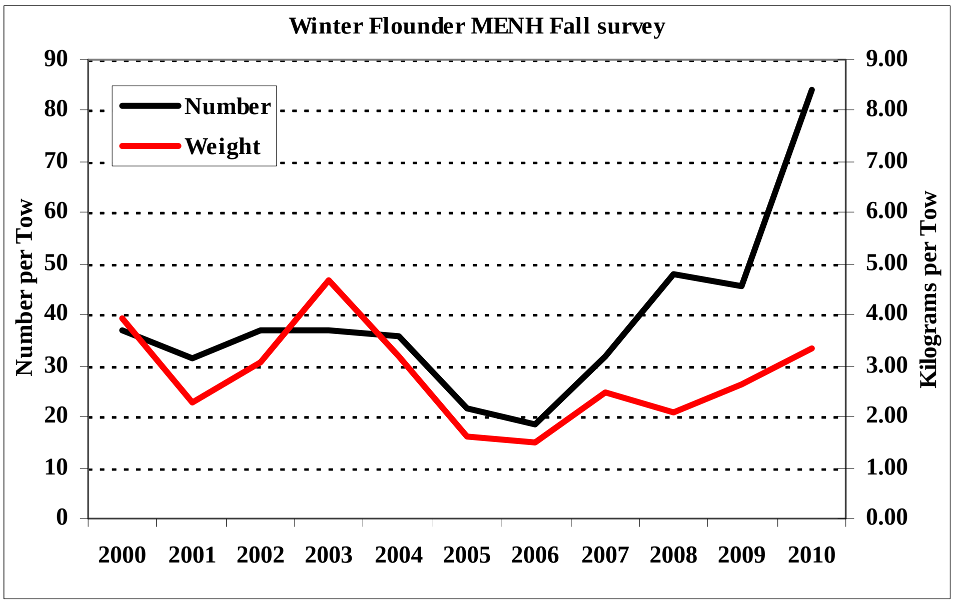
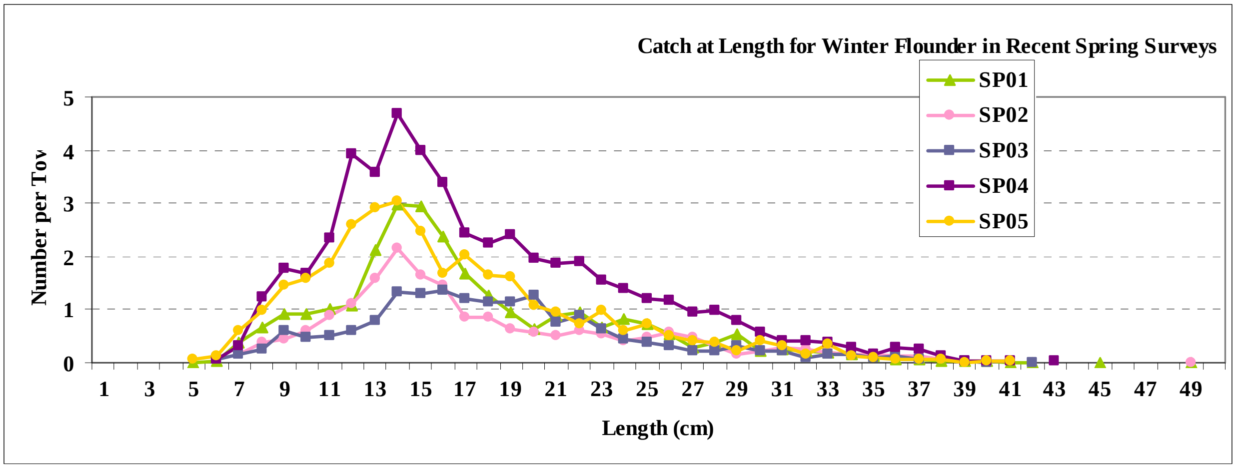


Figure C19. Spring and Fall MENH bottom trawl survey winter flounder abundance indices.



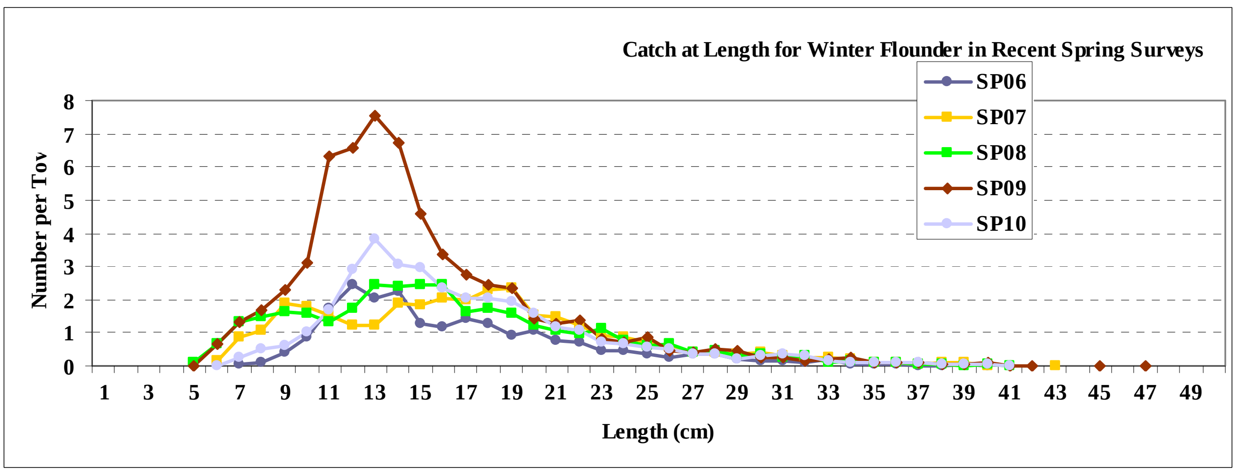
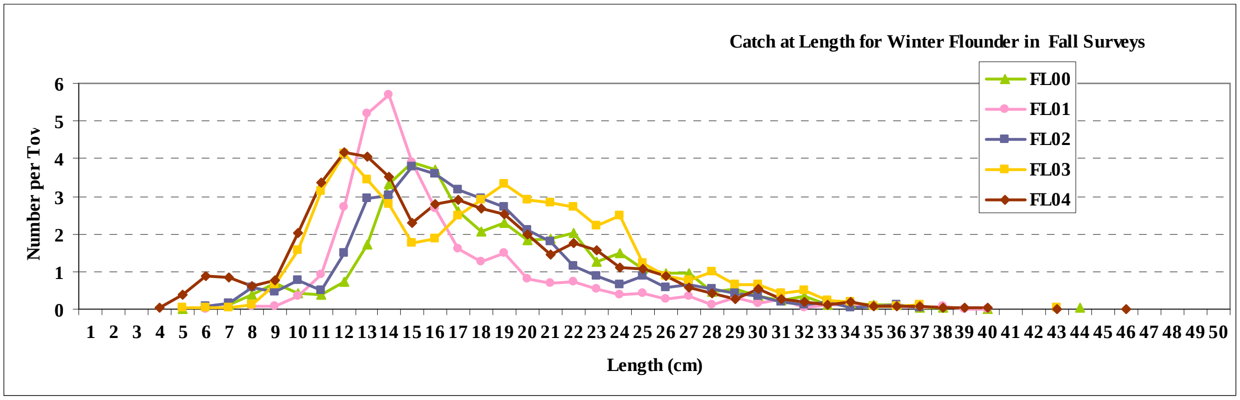


Figure C20. Spring MENH survey length distributions for Gulf of Maine winter flounder.



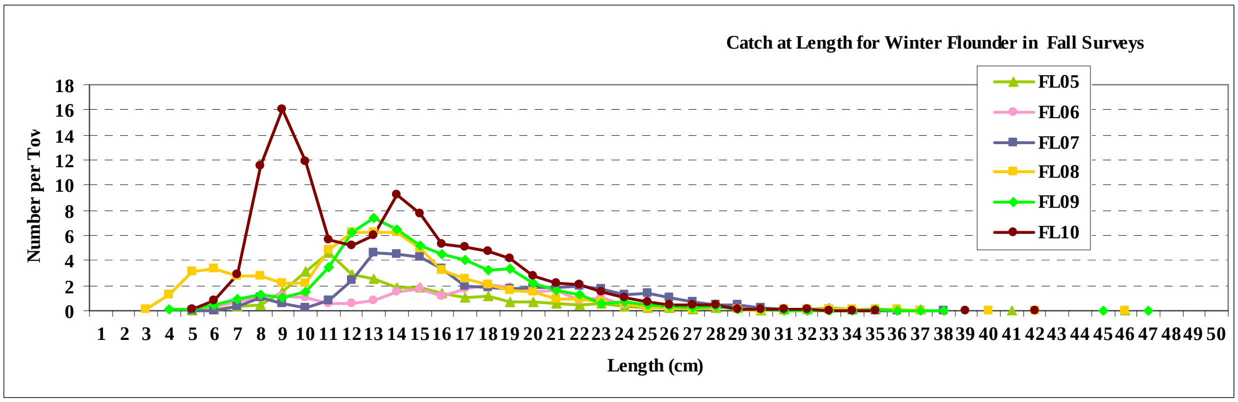


Figure C21. Fall MENH survey length distributions for Gulf of Maine winter flounder.

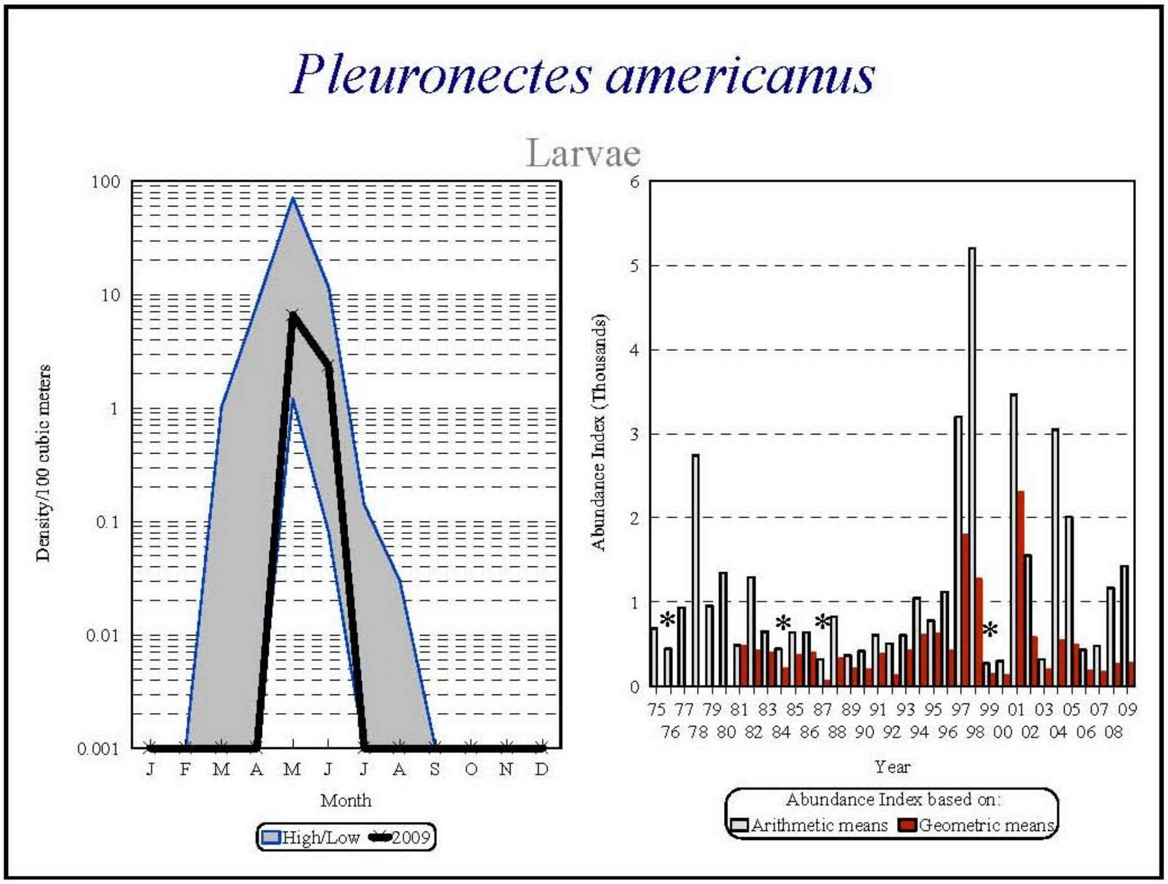


Figure C22. Entrainment monitoring of winter flounder larvae at the Pilgrim Nuclear power plant in Plymouth Massachusetts from 1975 to 2009.

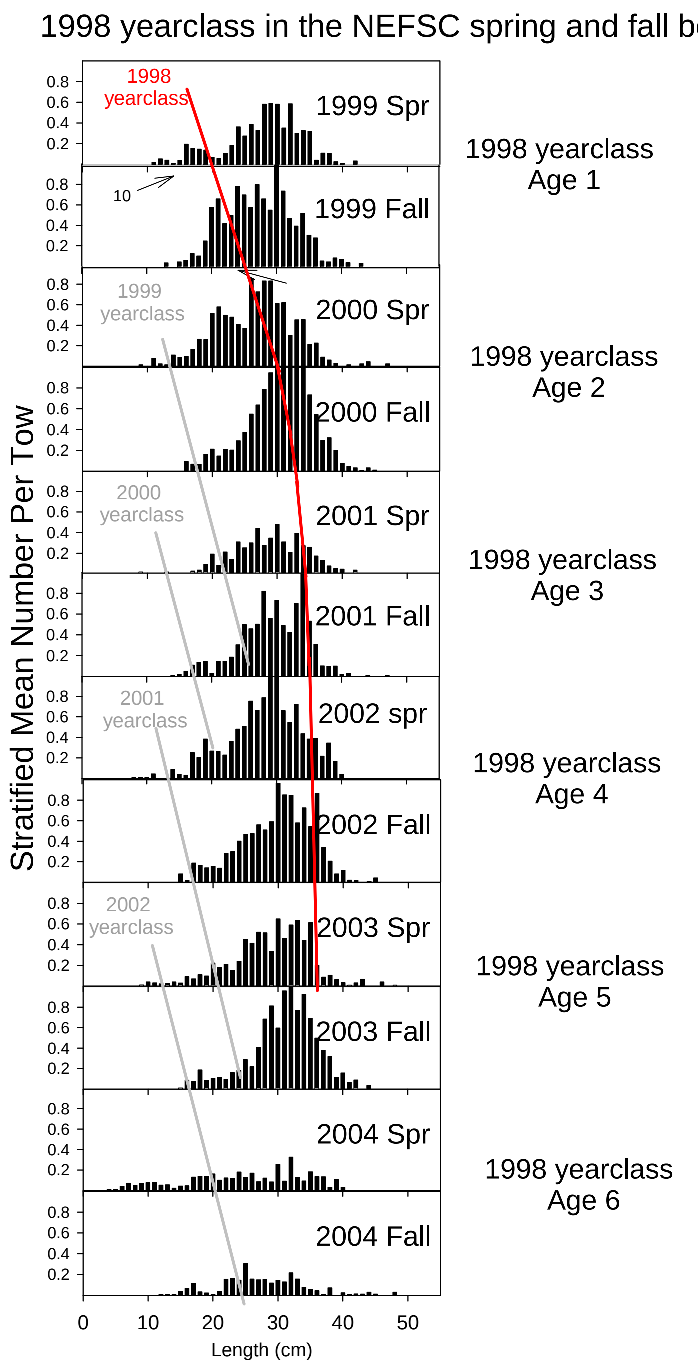


Figure C23. MDMF bottom trawl survey tracking of the 1998 yearclass in the Gulf of Maine winter flounder catch per tow at length (cm) distributions.

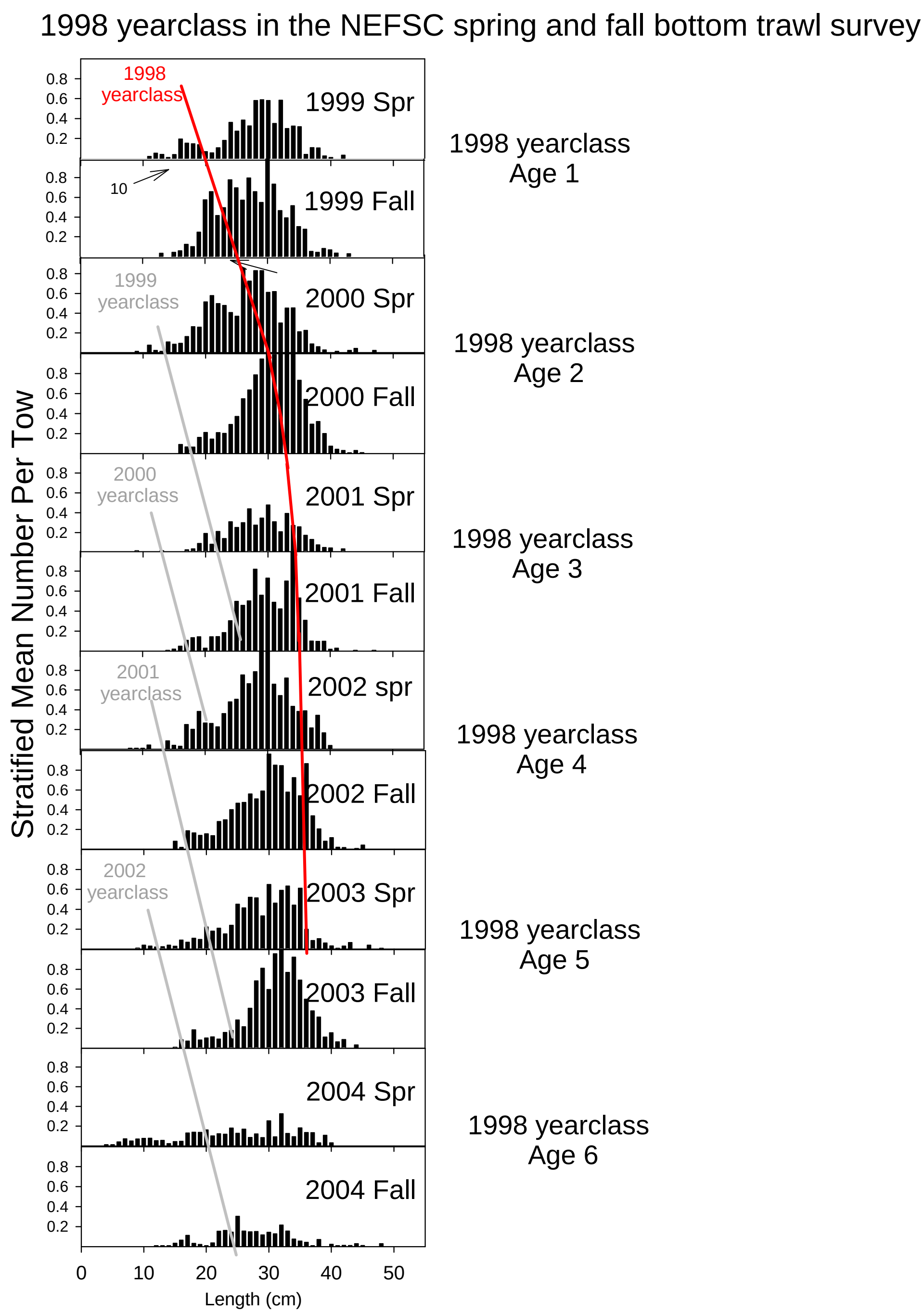


Figure C24. NEFSC bottom trawl survey tracking of the 1998 yearclass in the Gulf of Maine winter flounder catch per tow at length (cm) distributions.

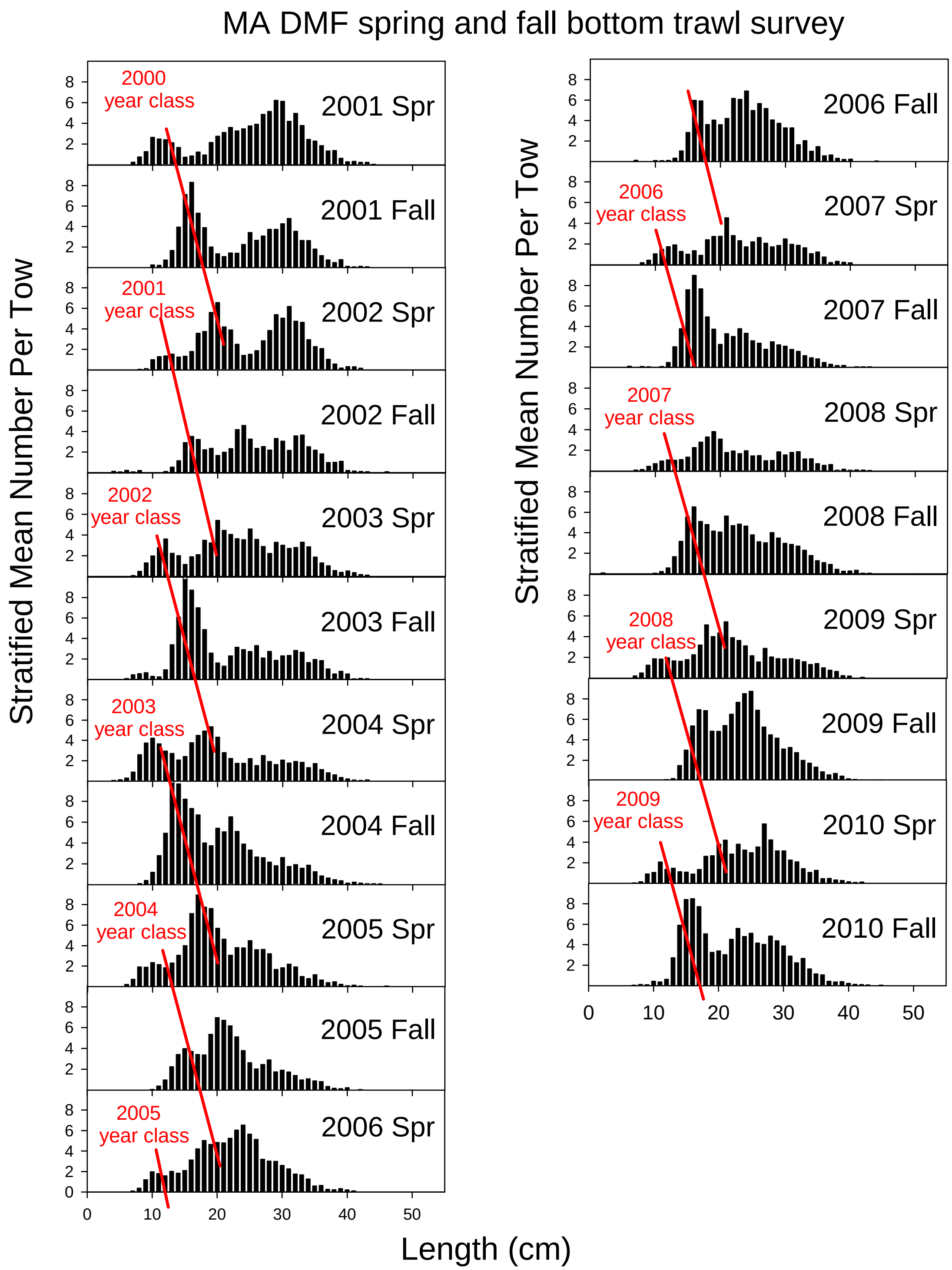


Figure C25. MDMF bottom trawl survey tracking of age modes in the catch per tow at length (cm) distributions from the spring and fall surveys for Gulf of Maine winter flounder.

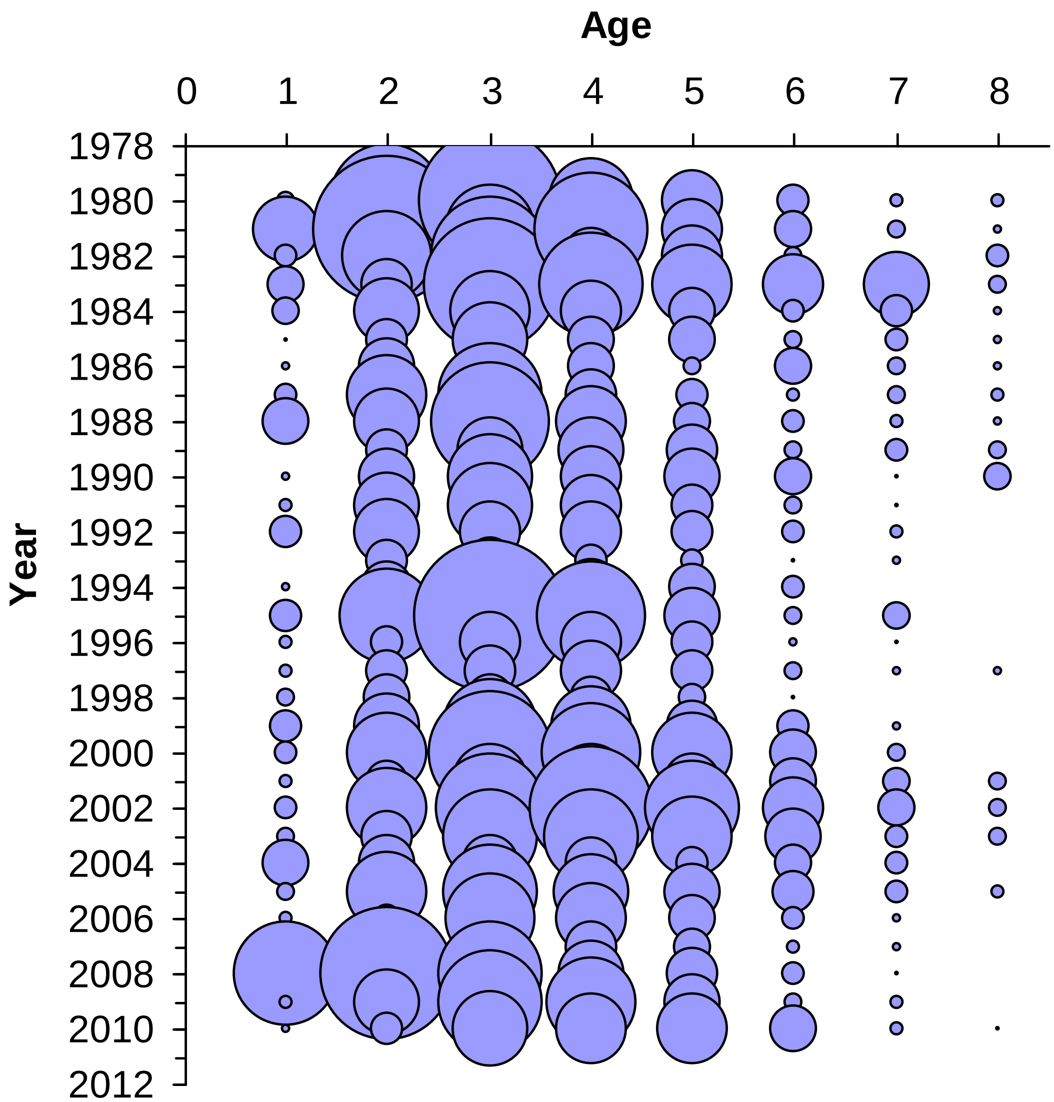


Figure C26. NEFSC Spring indices of abundance by age.

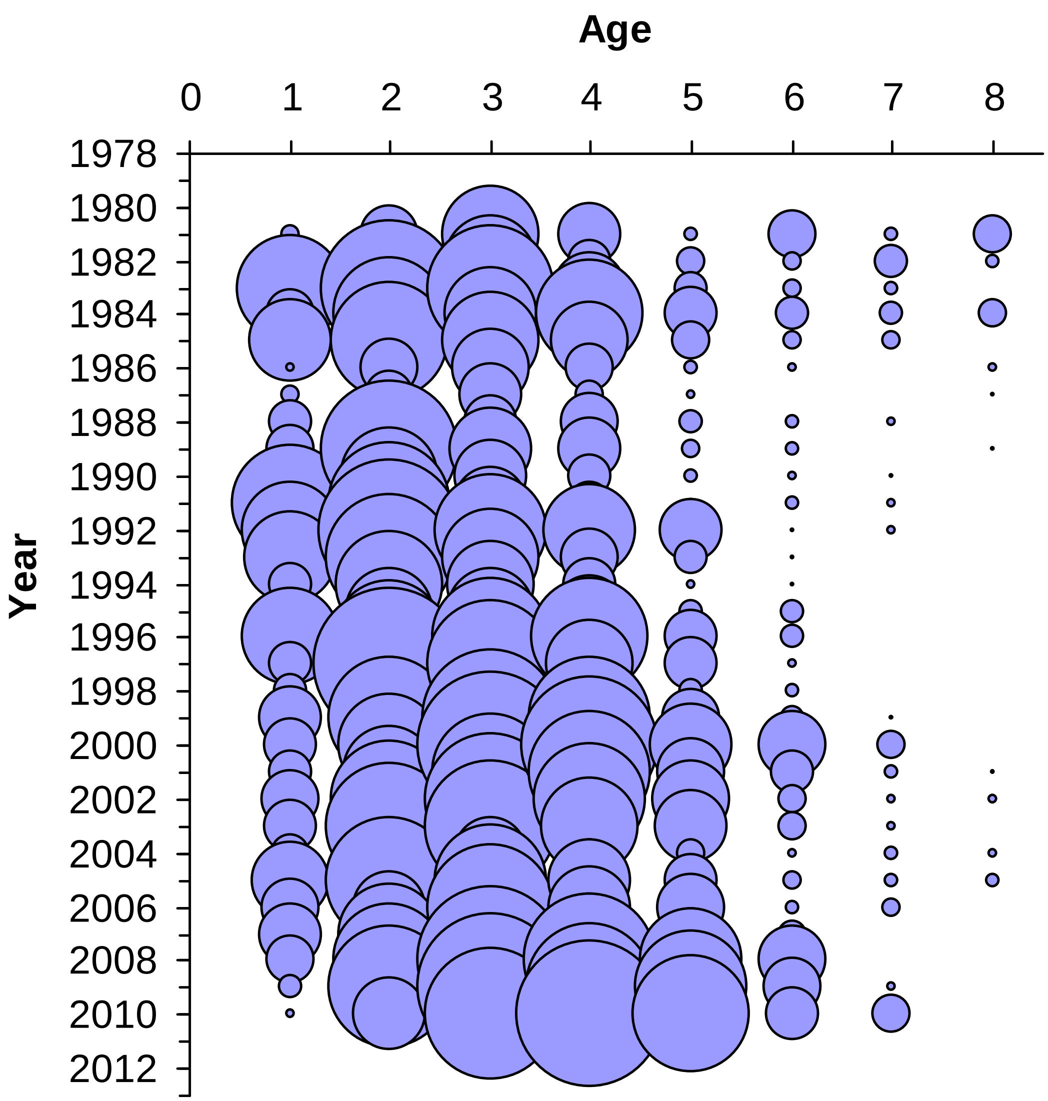


Figure C27. NEFSC Fall indices of abundance by age.

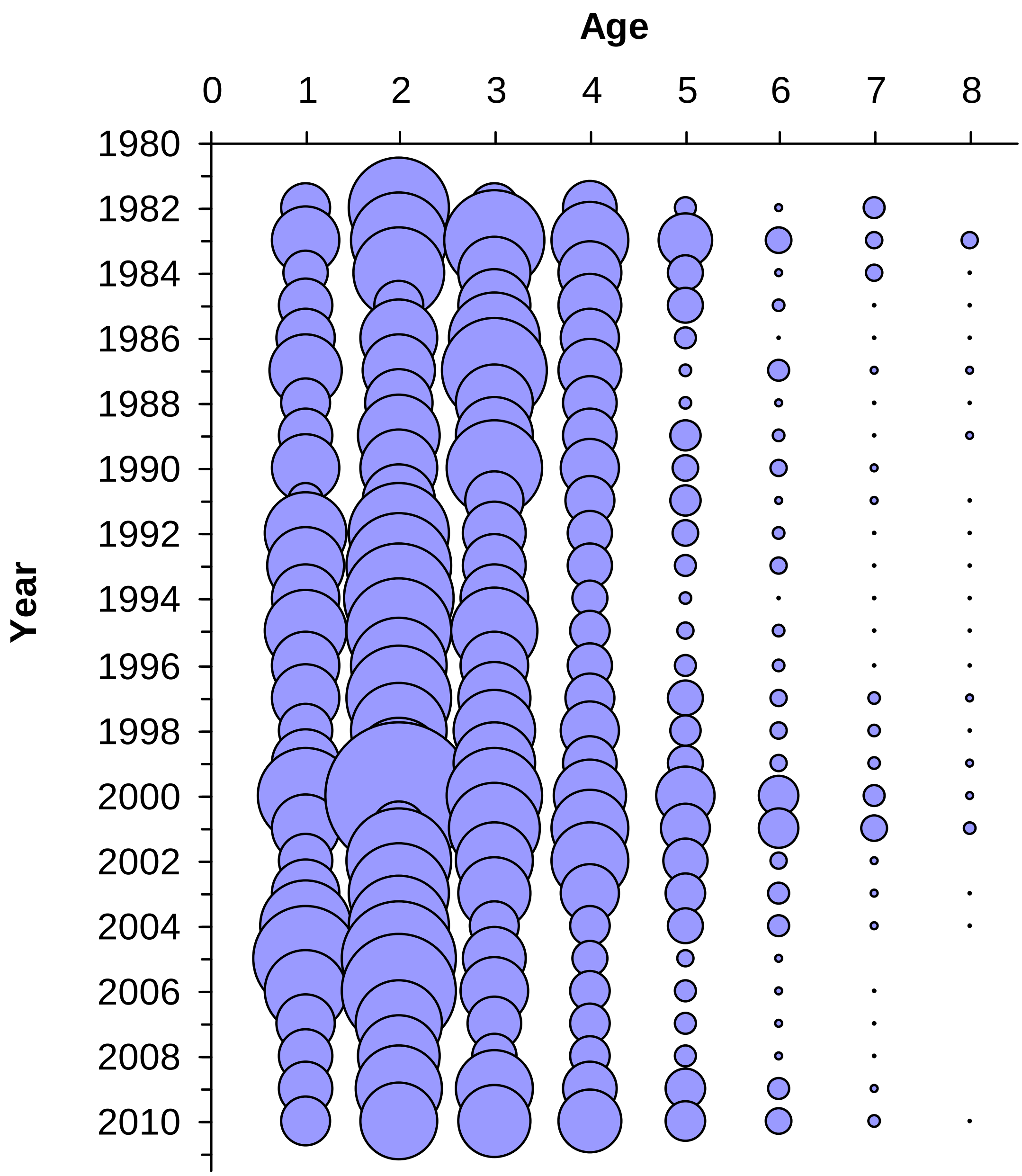


Figure C28. MDMF spring indices of abundance by age.

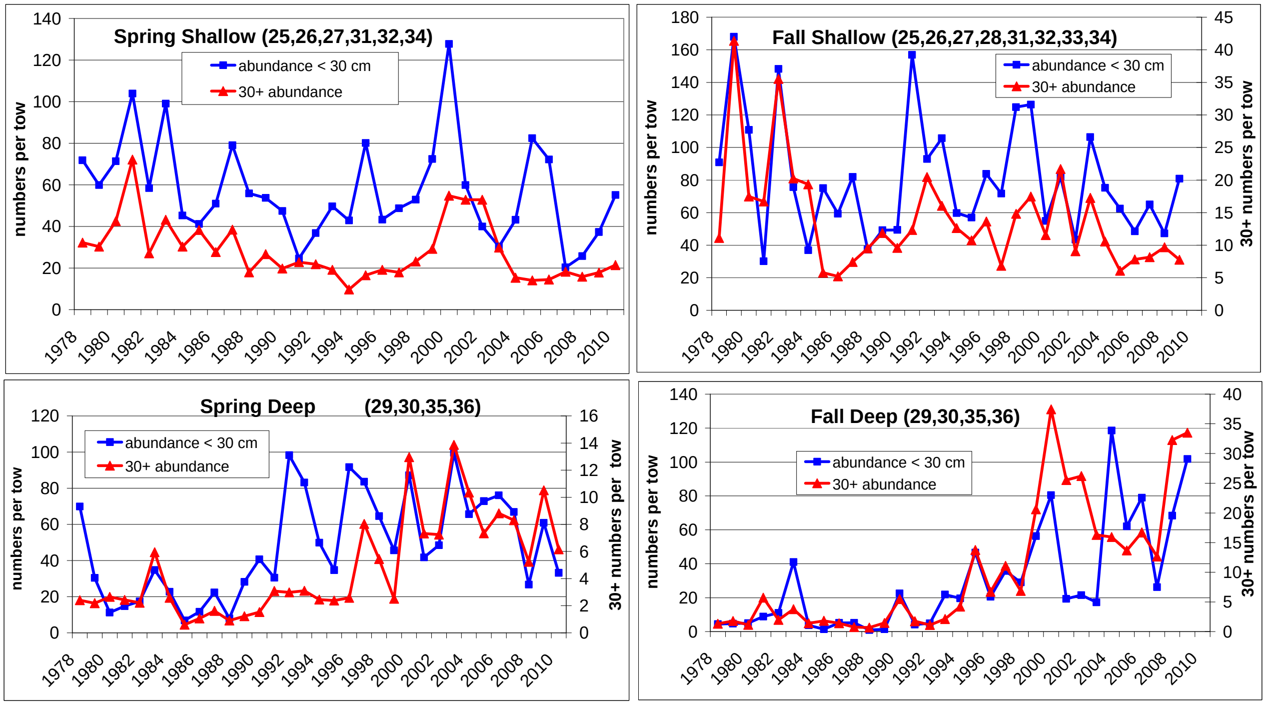


Figure C29. Stratified number per tow indices greater than and less than 30 cm from the Spring and Fall MDMF surveys by depth category (shallow and deep).

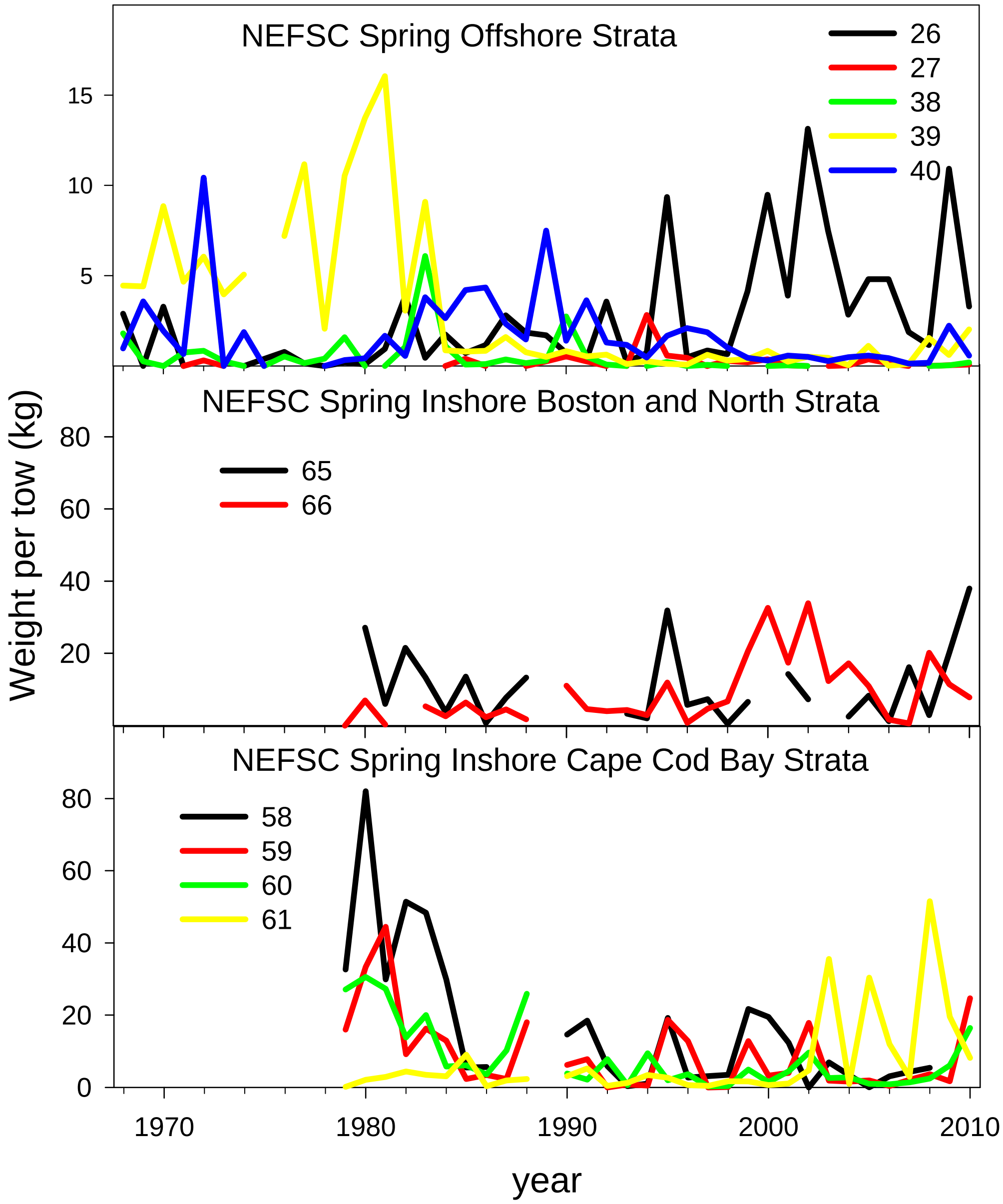


Figure C30. Spring NEFSC survey weight per tow by strata indices.

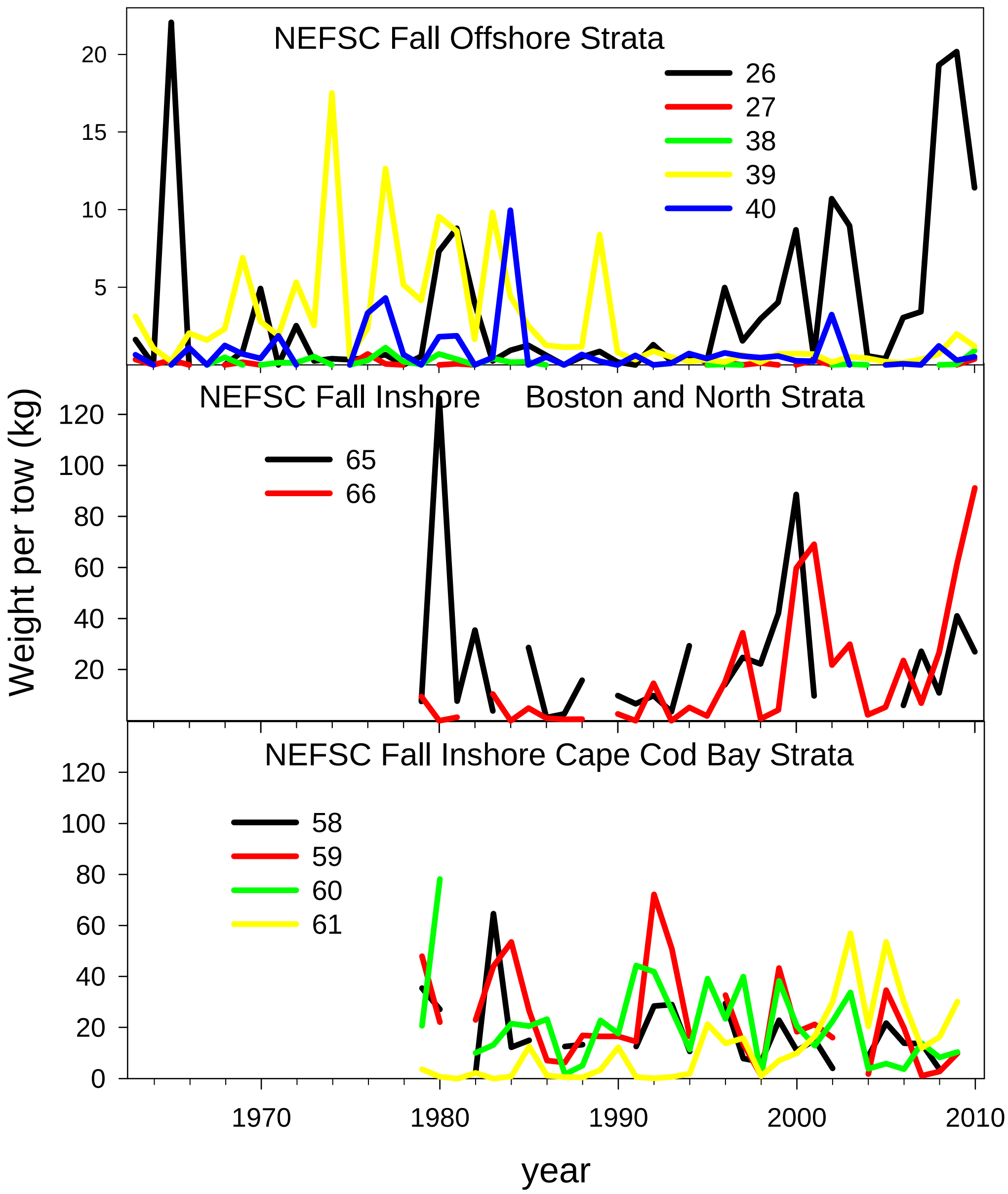


Figure C31. Spring NEFSC survey weight per tow by strata indices.

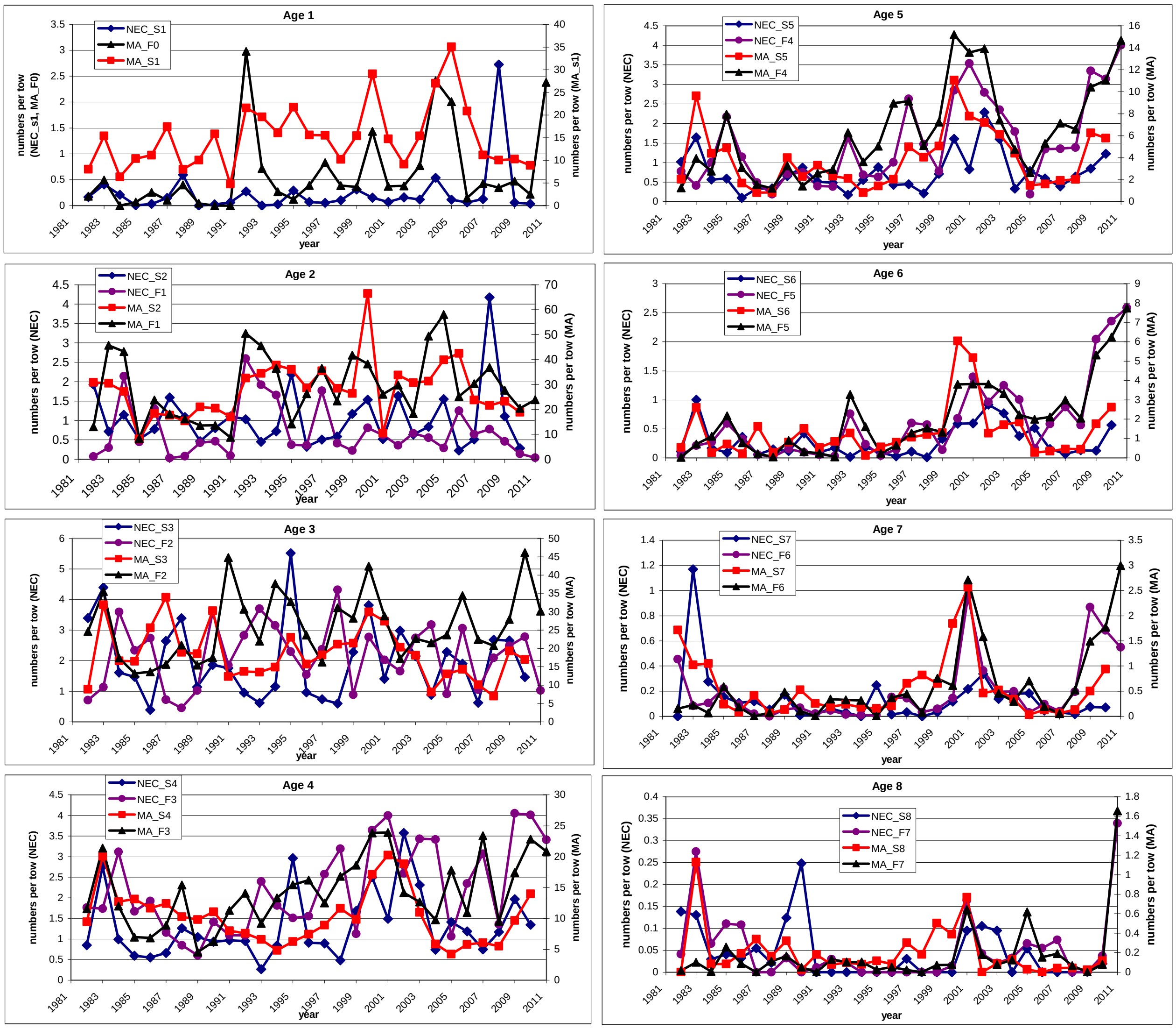


Figure C32. Indices at age from the spring and fall NEFSC and MDMF surveys.

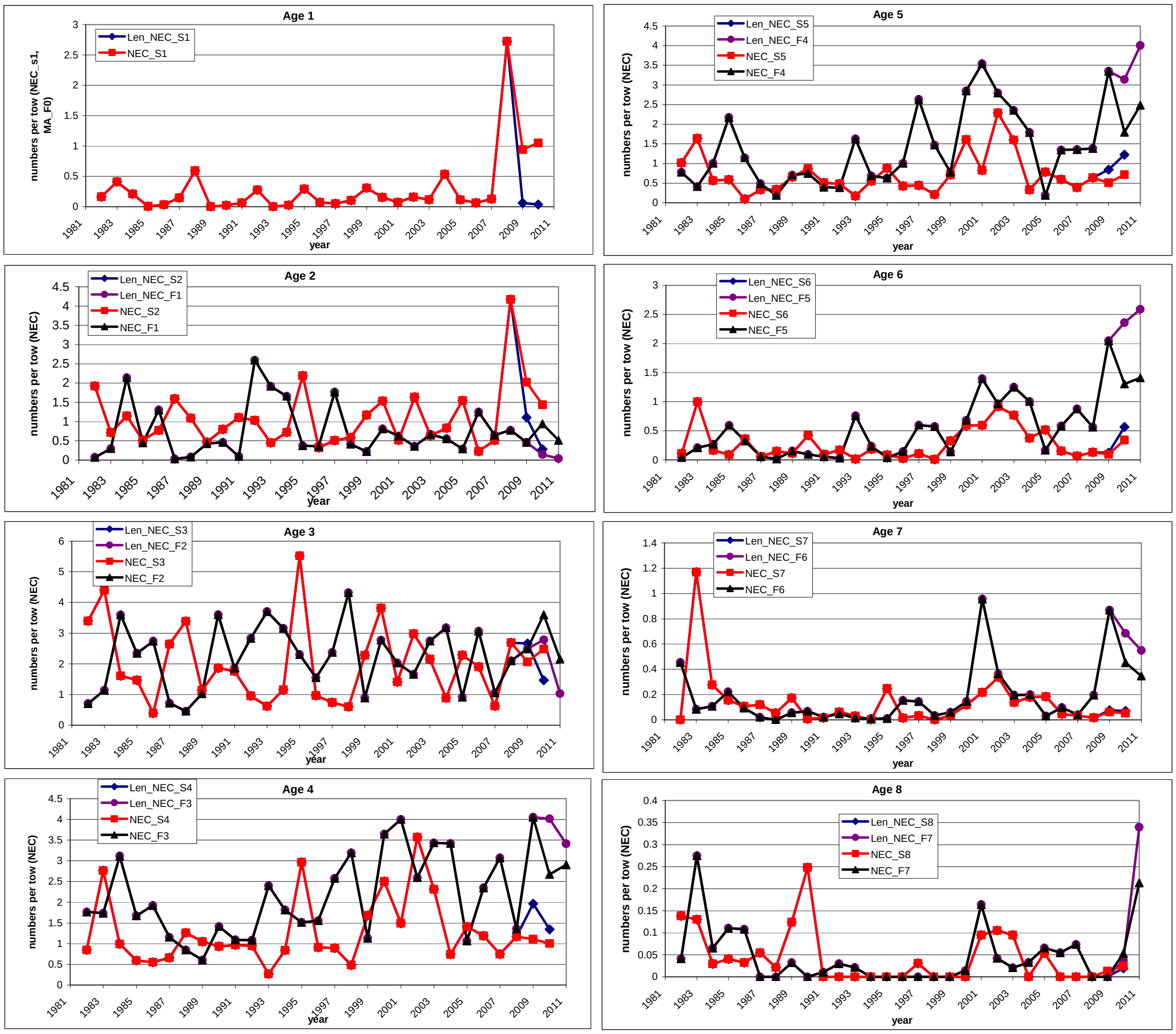


Figure C33. Aggregate and length based converted indices at age from the spring and fall NEFSC surveys.

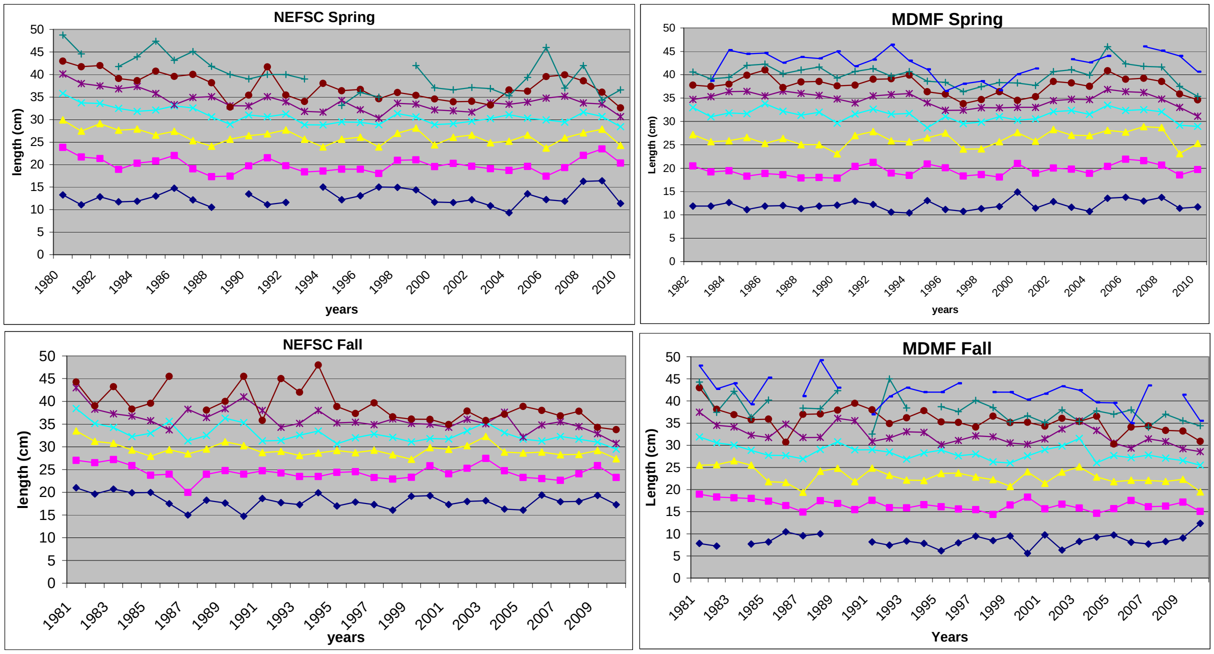


Figure C34. Mean lengths at age from the NEFSC and MDMF surveys.

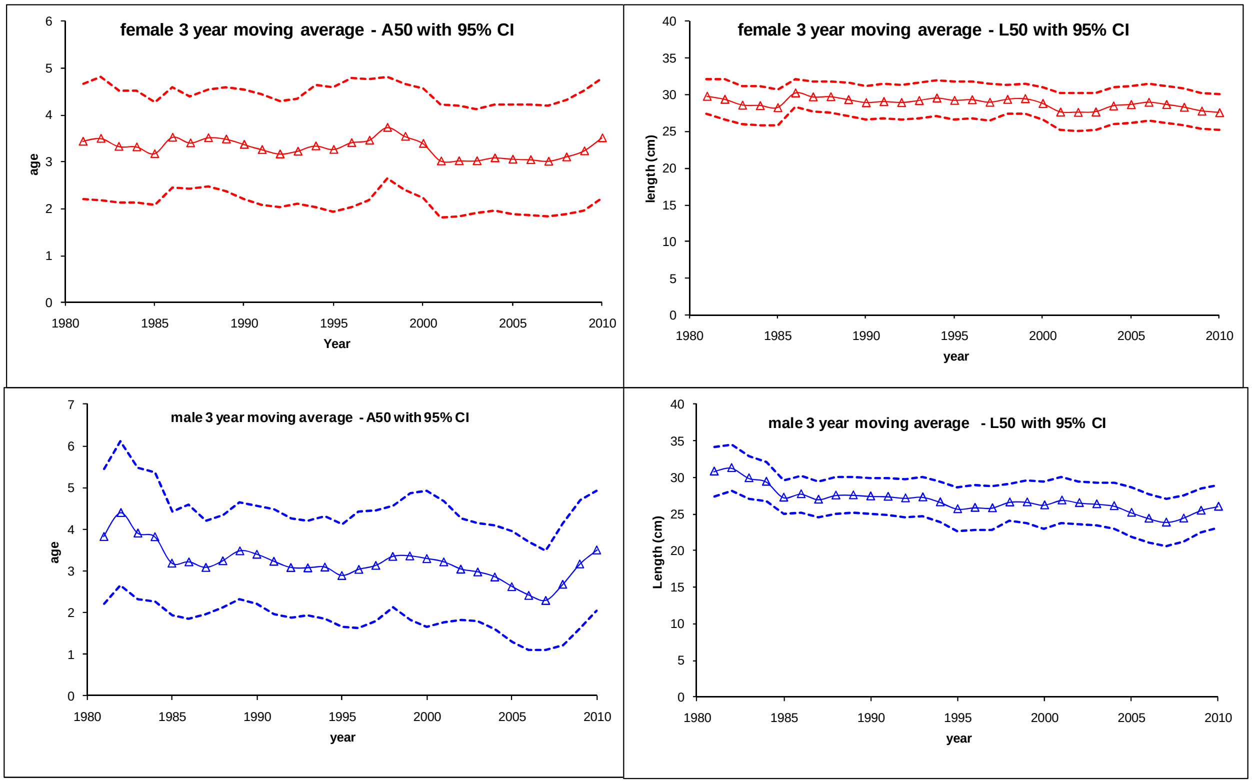
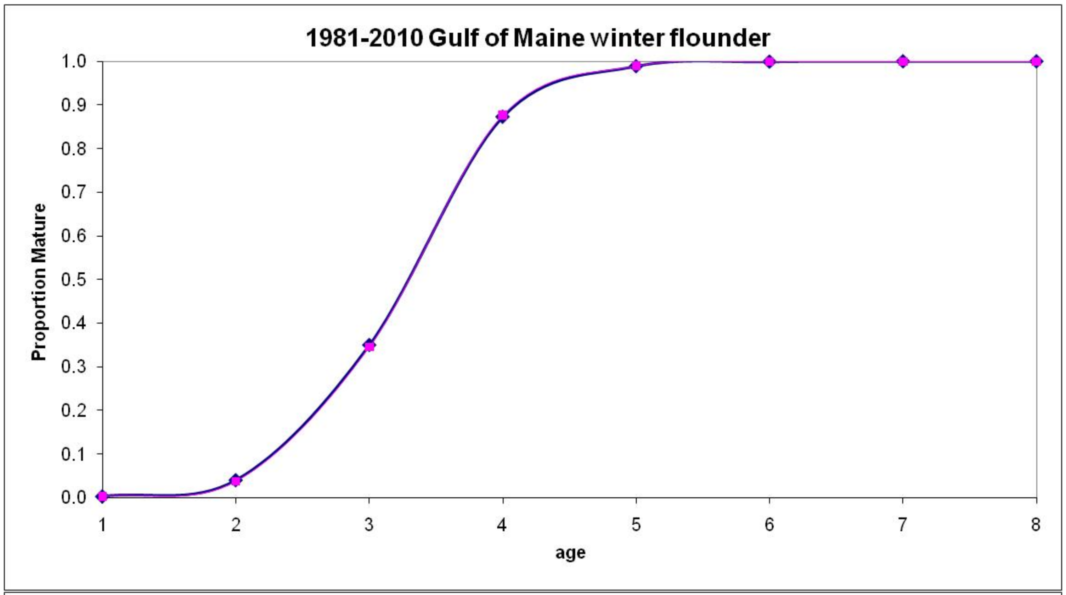


Figure C35. Male and female 3 year moving average L and A 50s from the MDMF survey.



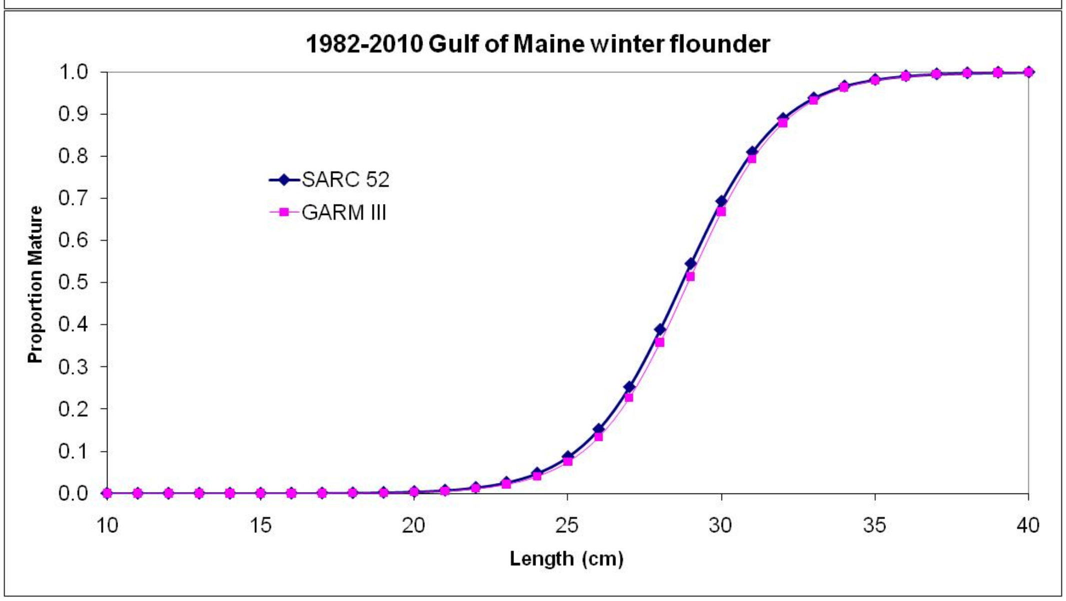
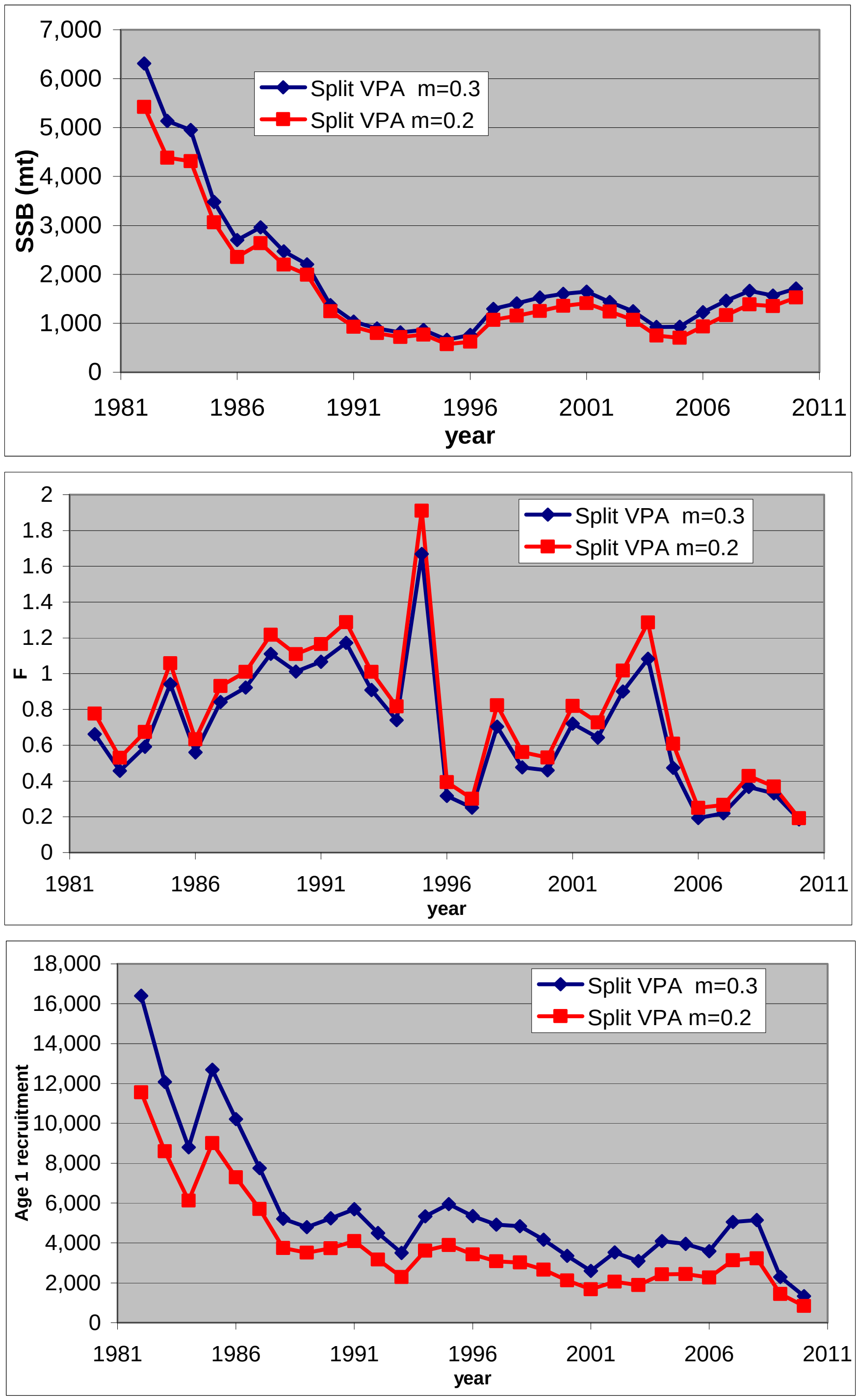


Figure C36. Female Gulf of Maine winter flounder logistic length and age maturity curves estimated from GARM III (1982-2007, n = 12,108) and with all years combine from the MDMF spring survey.



Figures C37. Split VPA SSB, F, and recruitment assuming m=0.2 and m=0.3.

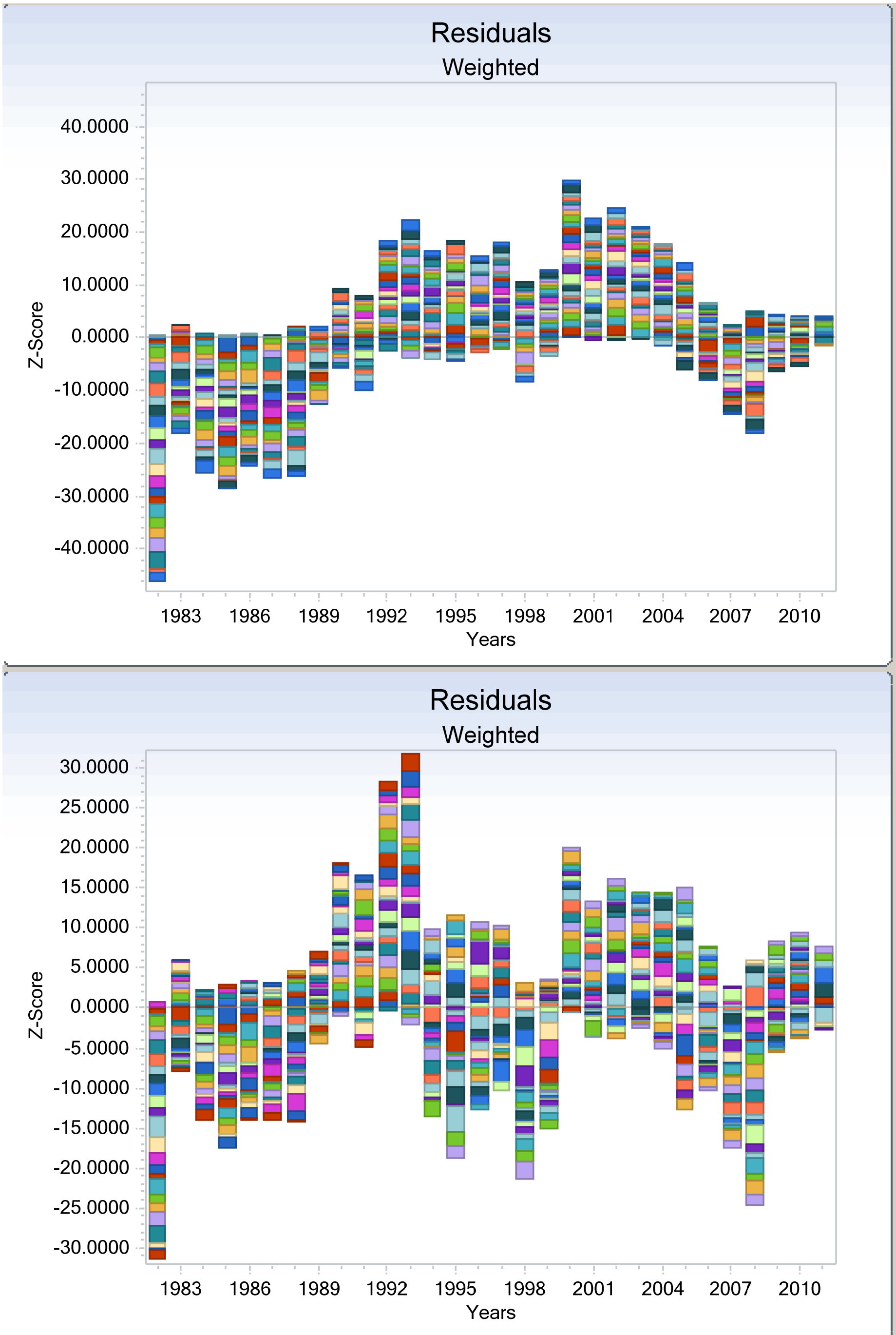


Figure C38. Base (top) and split (bottom) VPA residual pattern for all ages.

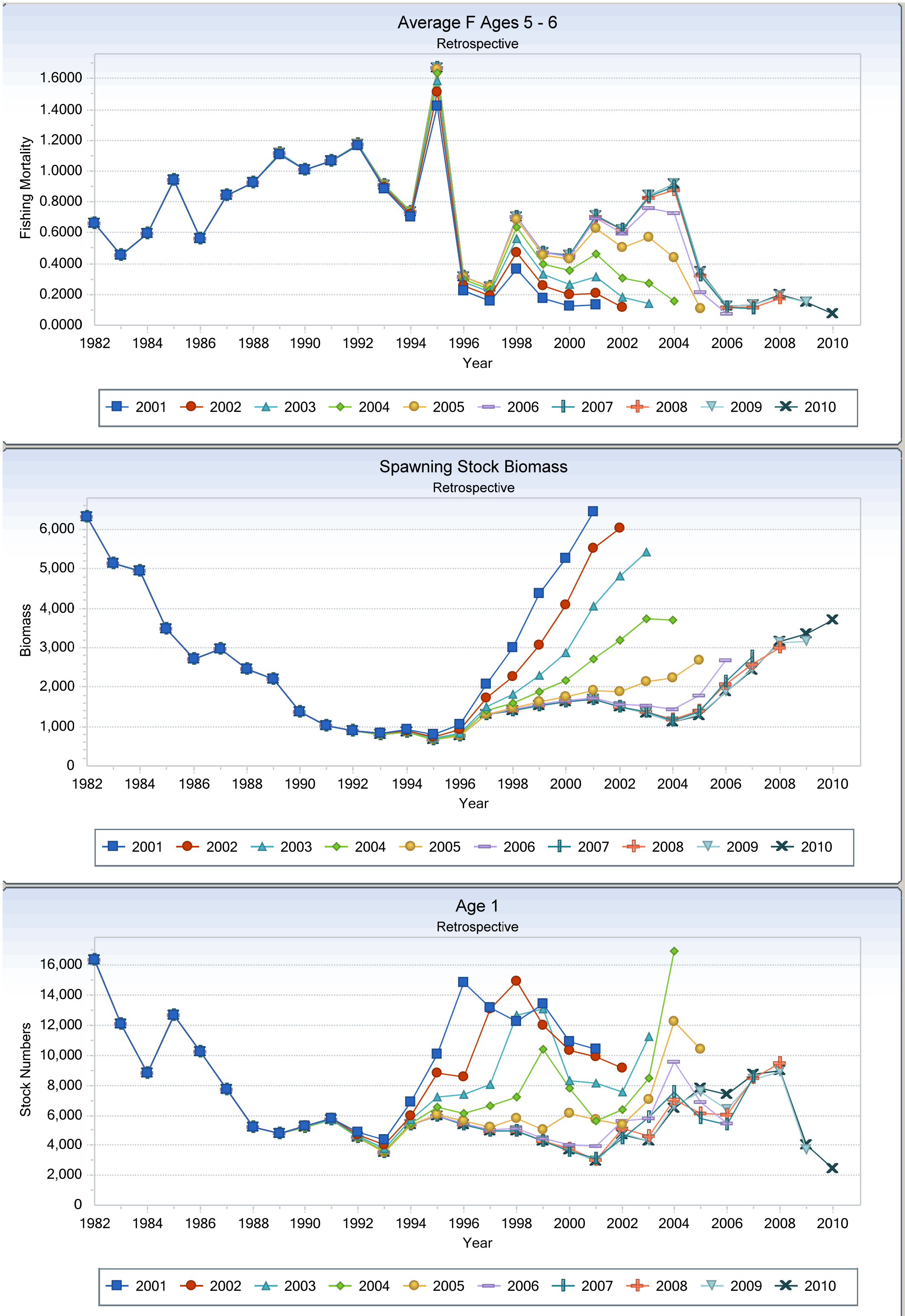


Figure C39. Gulf of Maine winter flounder Base VPA retrospective with m=0.3.

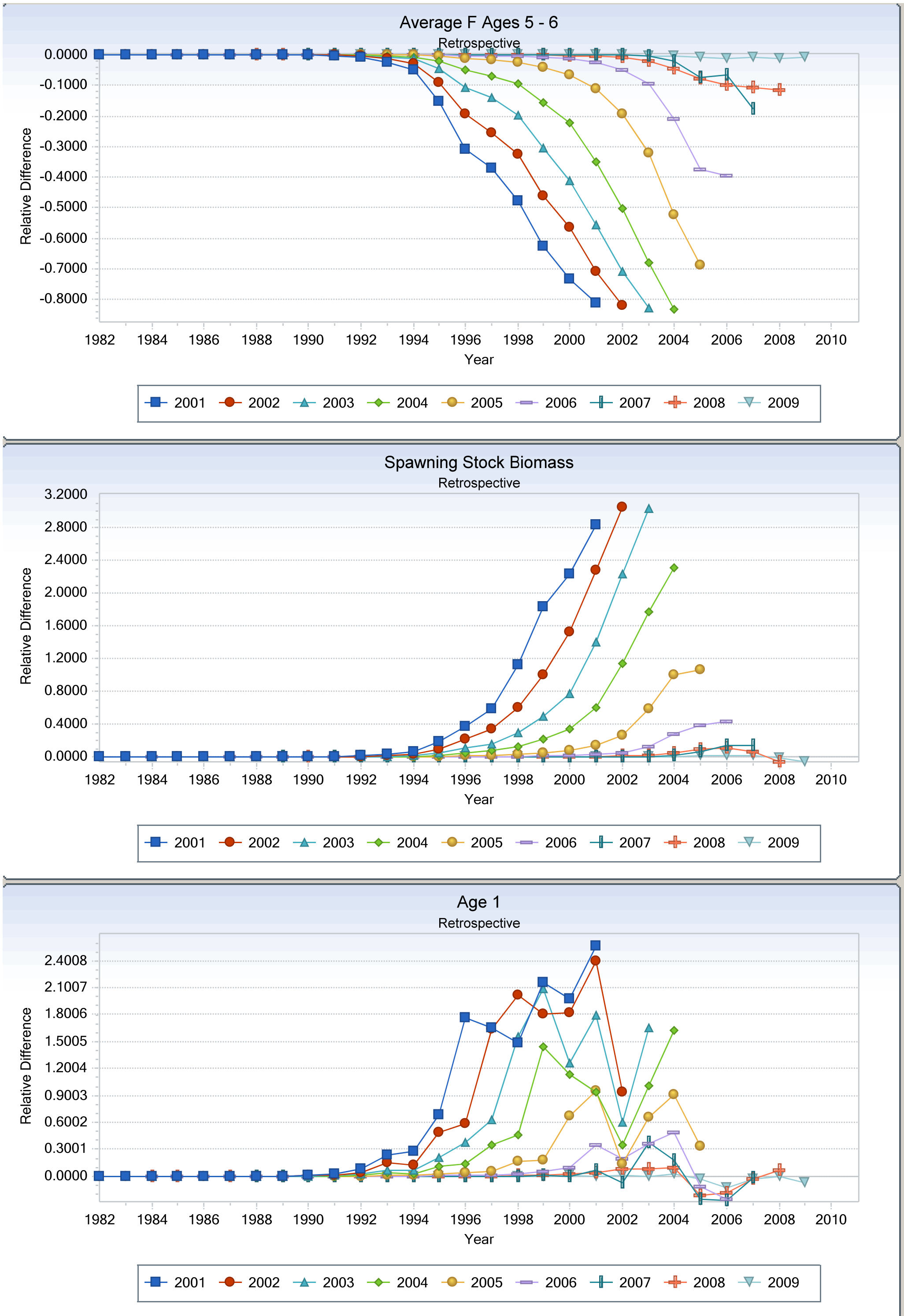


Figure C40. Gulf of Maine winter flounder Base VPA relative difference retrospective with m=0.3.

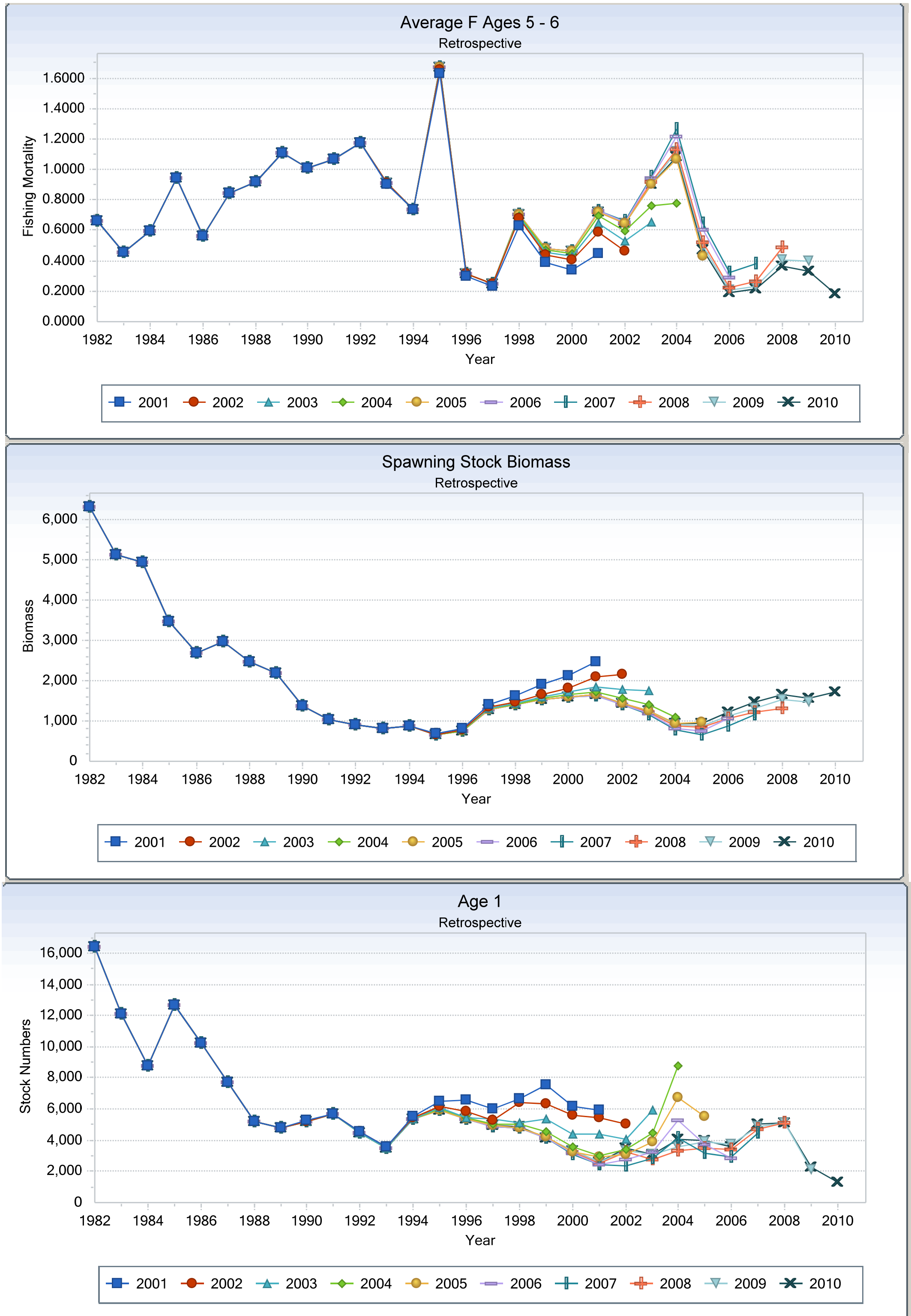


Figure C41. Gulf of Maine winter flounder split VPA retrospective with m=0.3.

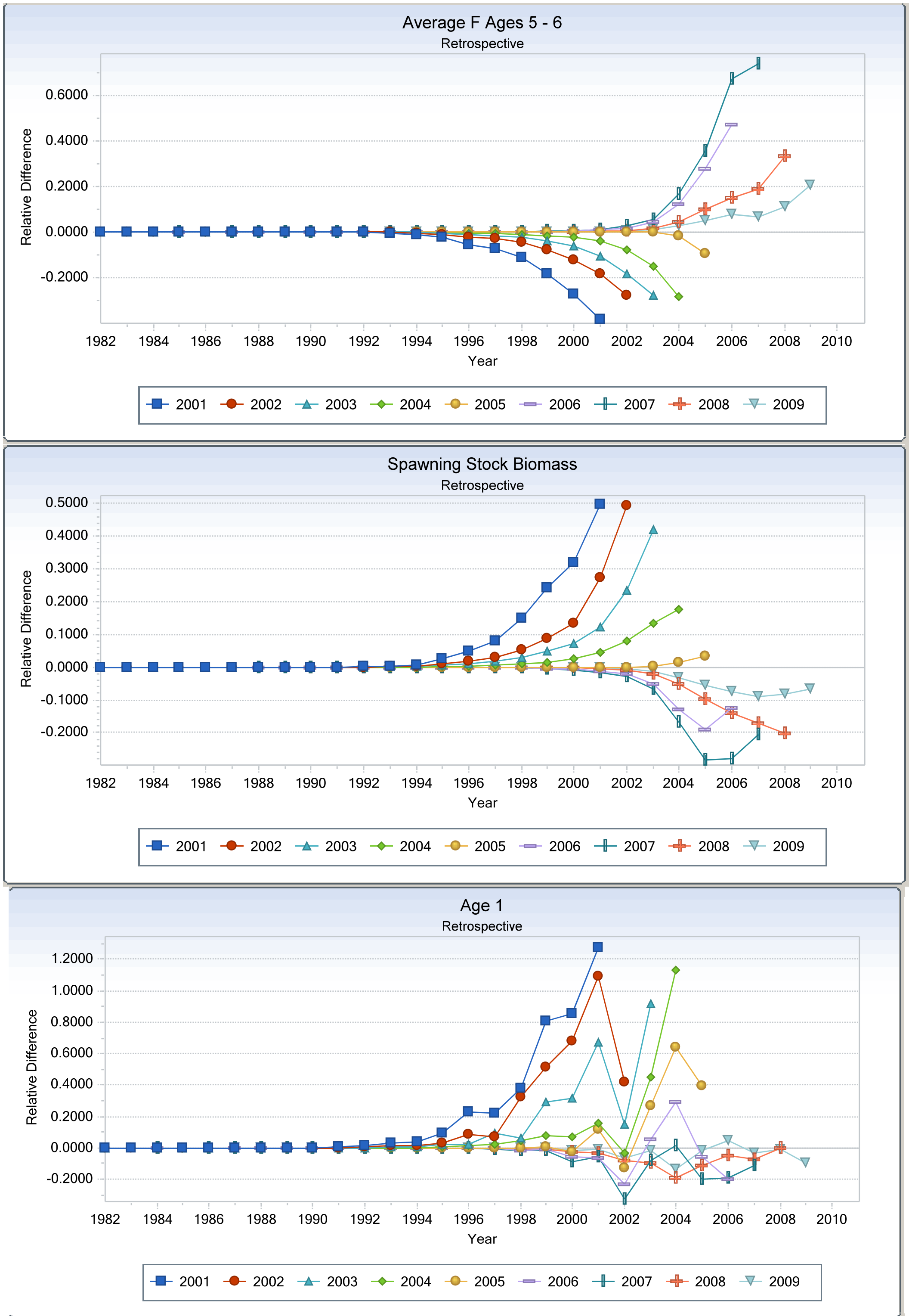


Figure C42. Gulf of Maine winter flounder split VPA relative difference retrospective with m=0.3.

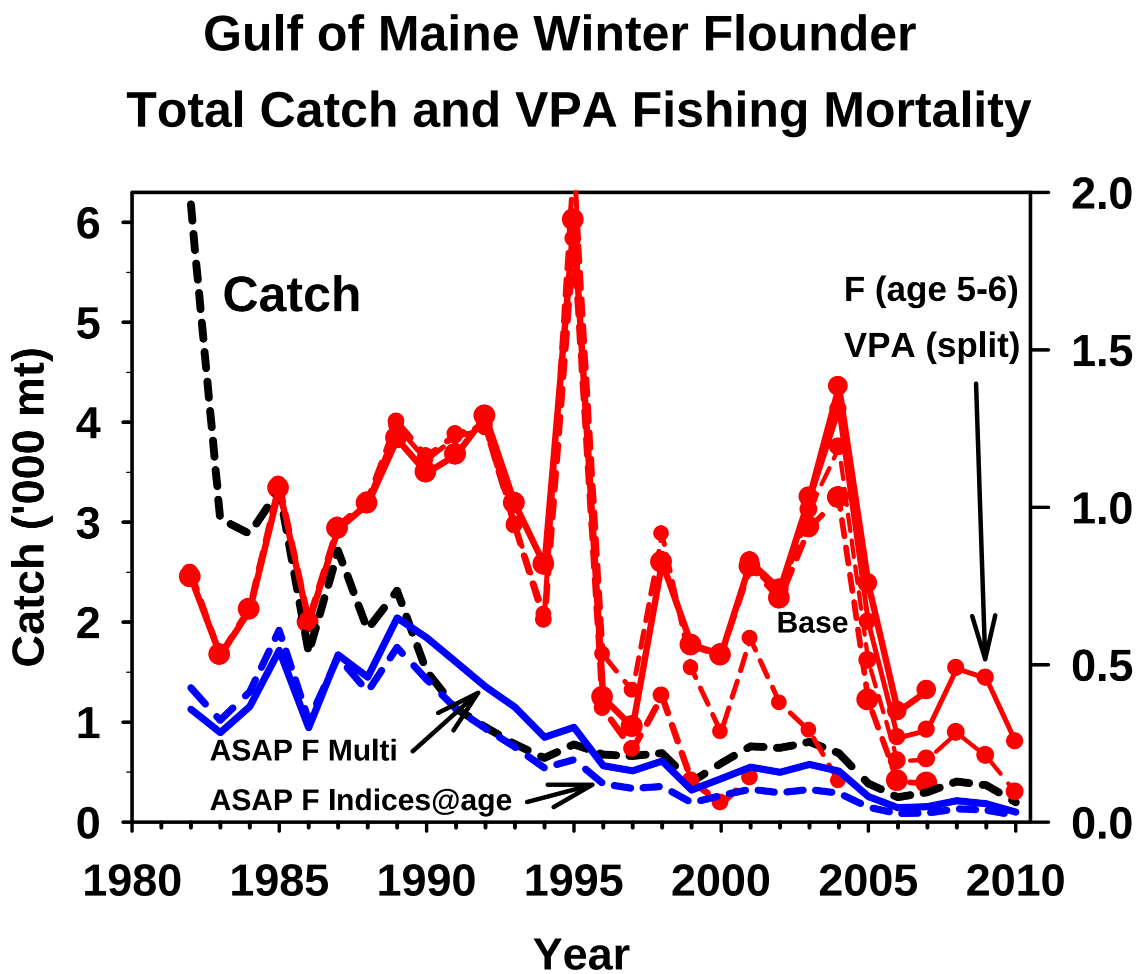


Figure C43. Total catch (landings and discards, thousands of metric tons) and fishing mortality rate (F, ages 5-6) from the split and base VPA runs from GARM I, II, and III, and this assessment for Gulf of Maine winter flounder. The ASAP indices at age and multi runs area also shown.

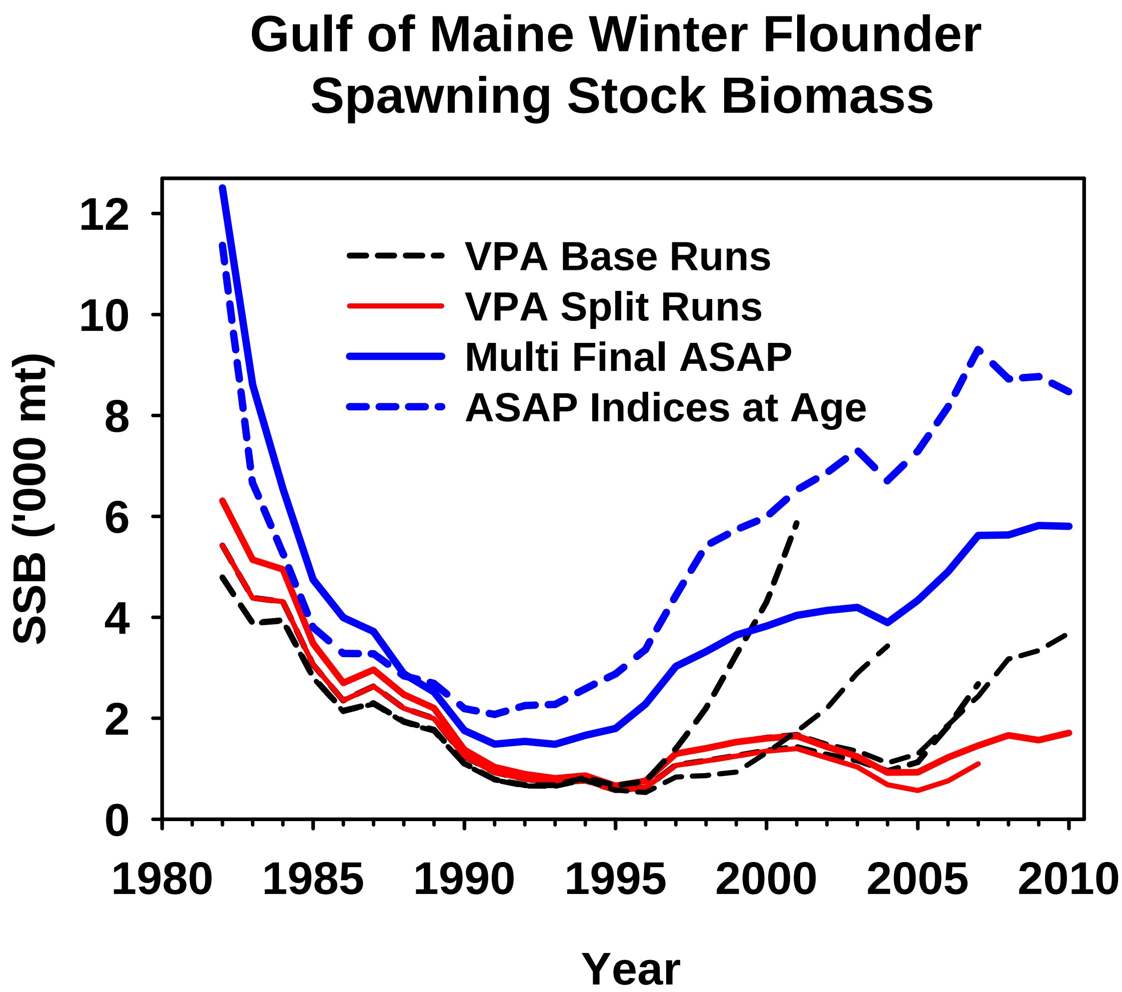


Figure C44. Spawning stock biomass from the split and base VPA runs from GARM I, II, III, and this assessment for Gulf of Maine winter flounder. The ASAP indices at age and multi runs area also shown.

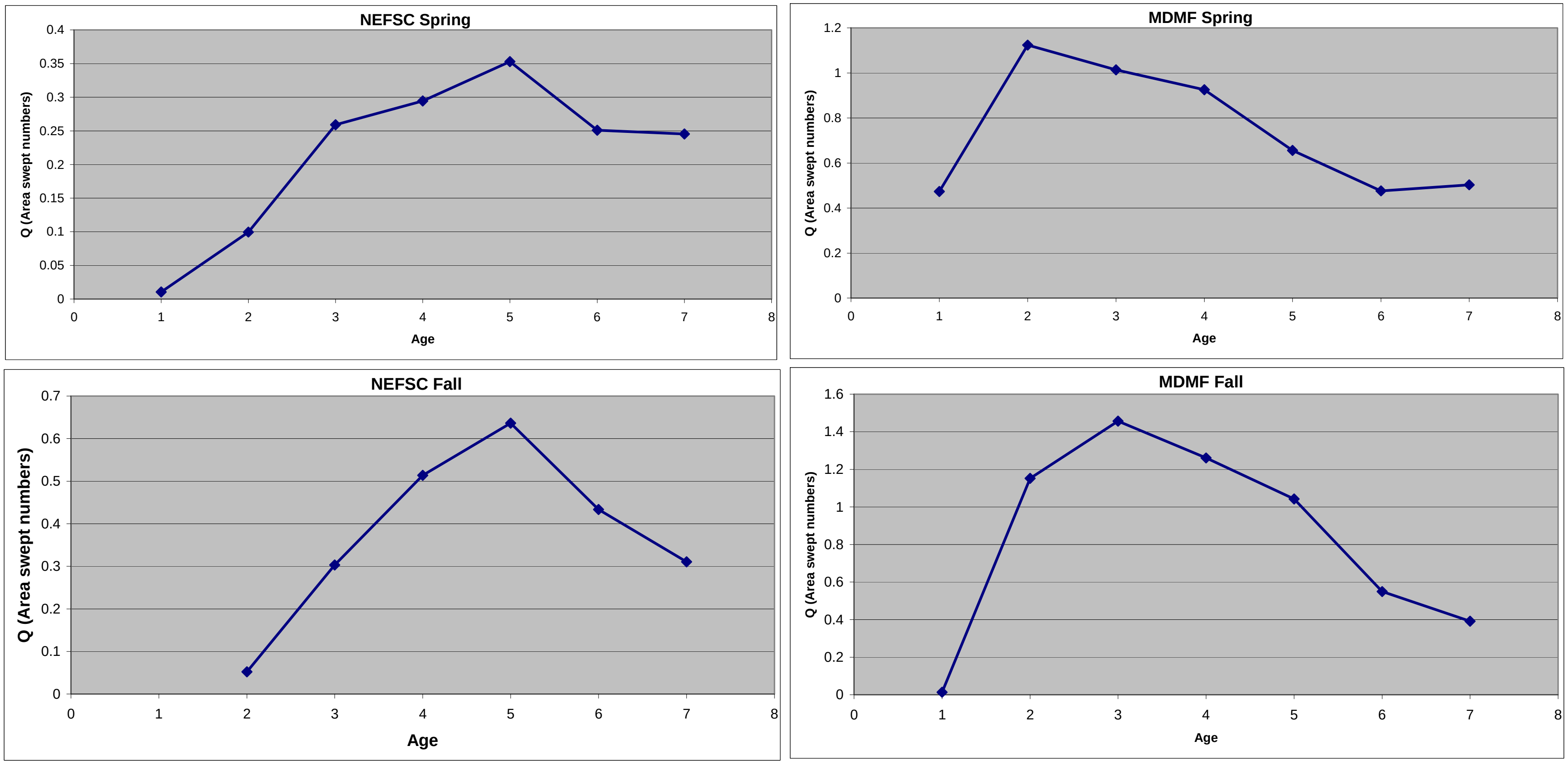


Figure C45. Estimated area swept Qs at age from the base VPA with m=0.3.

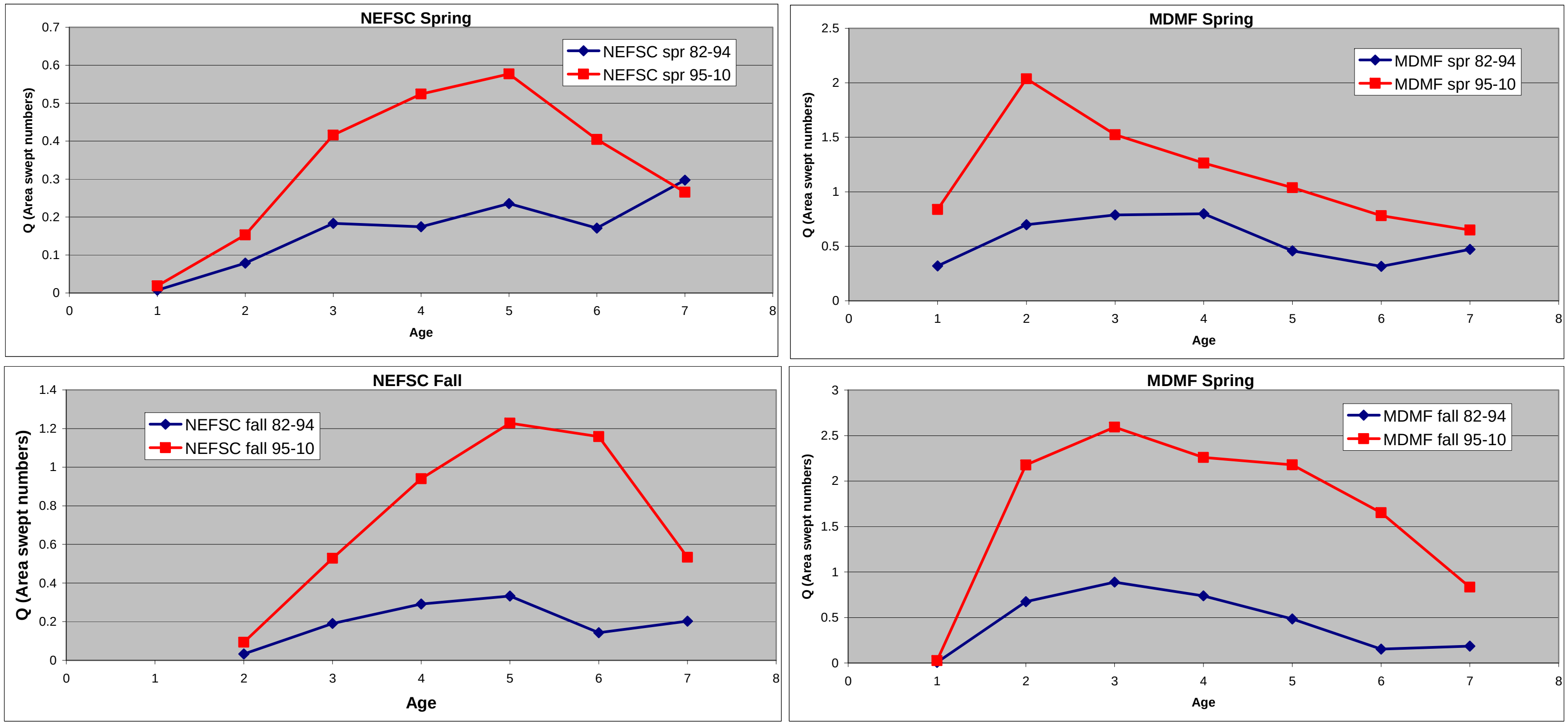


Figure C46. Estimated area swept Qs at age from the split VPA with m=0.3.

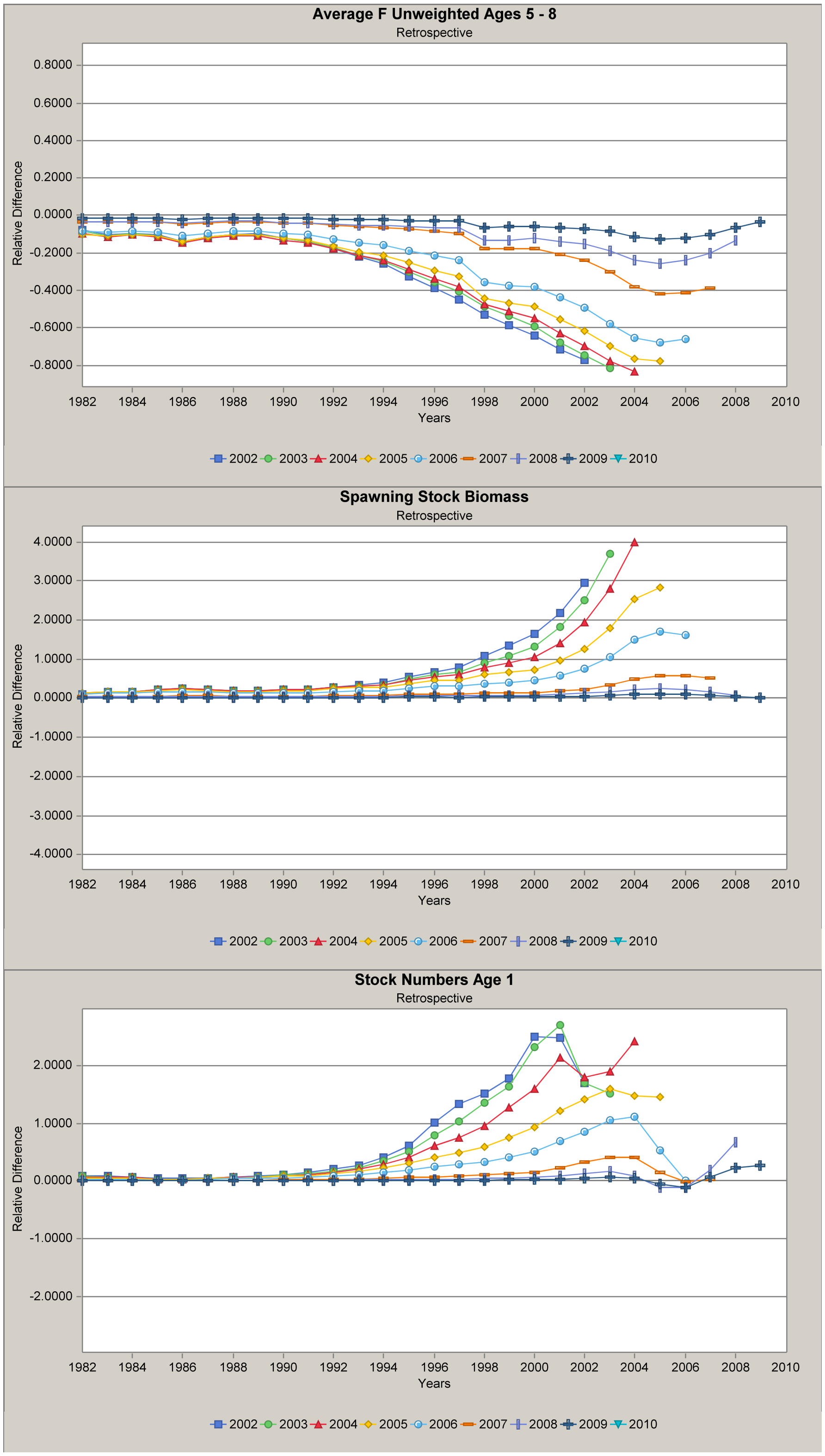


Figure C47. Relative retrospective pattern from ASAP indices at age run with a high effective sample size weight (ess 150) on the catch at age composition.

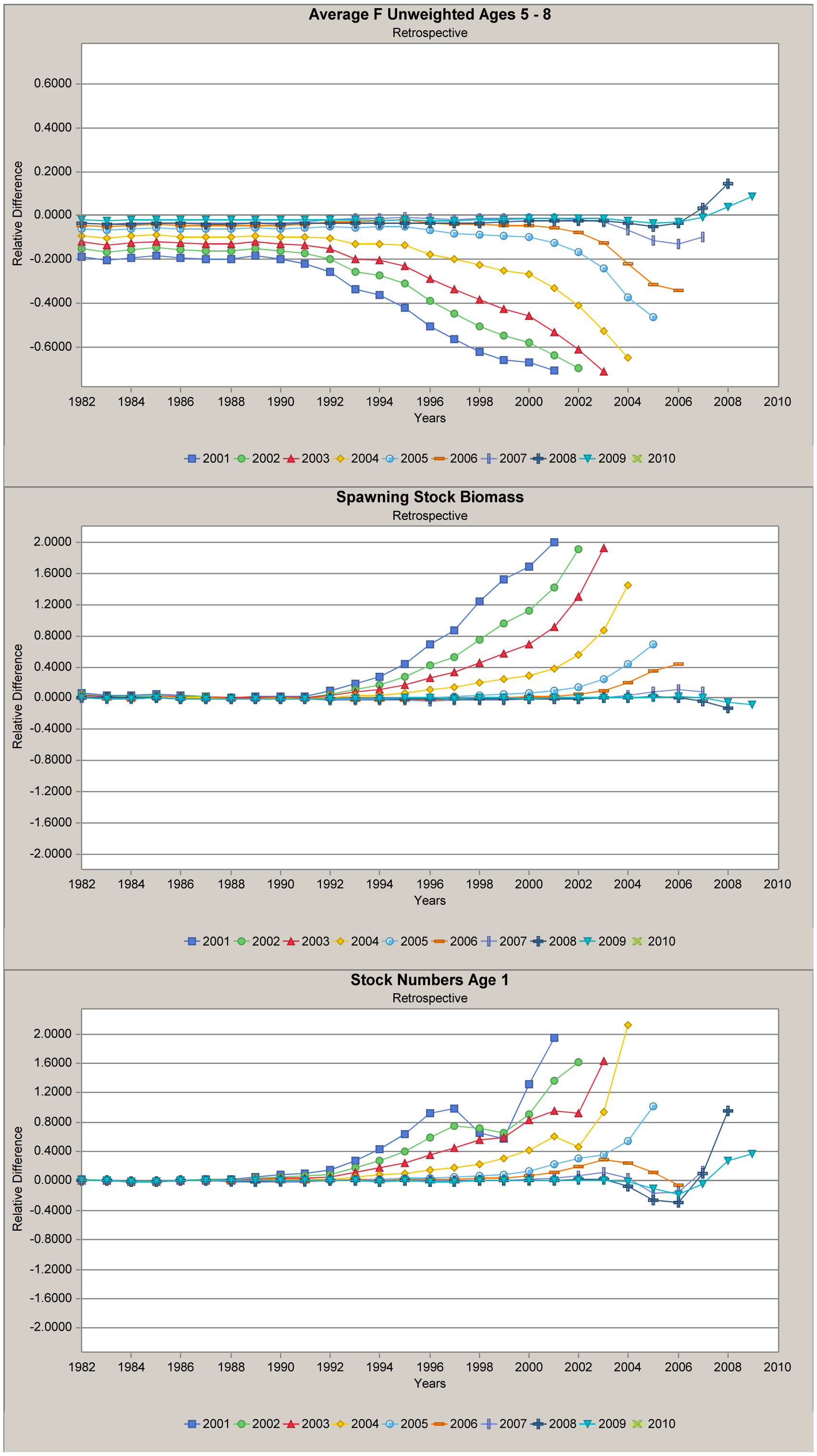


Figure C48. Relative retrospective pattern from the split ASAP indices at age run with a high effective sample size weight (ess 150) on the catch at age composition.

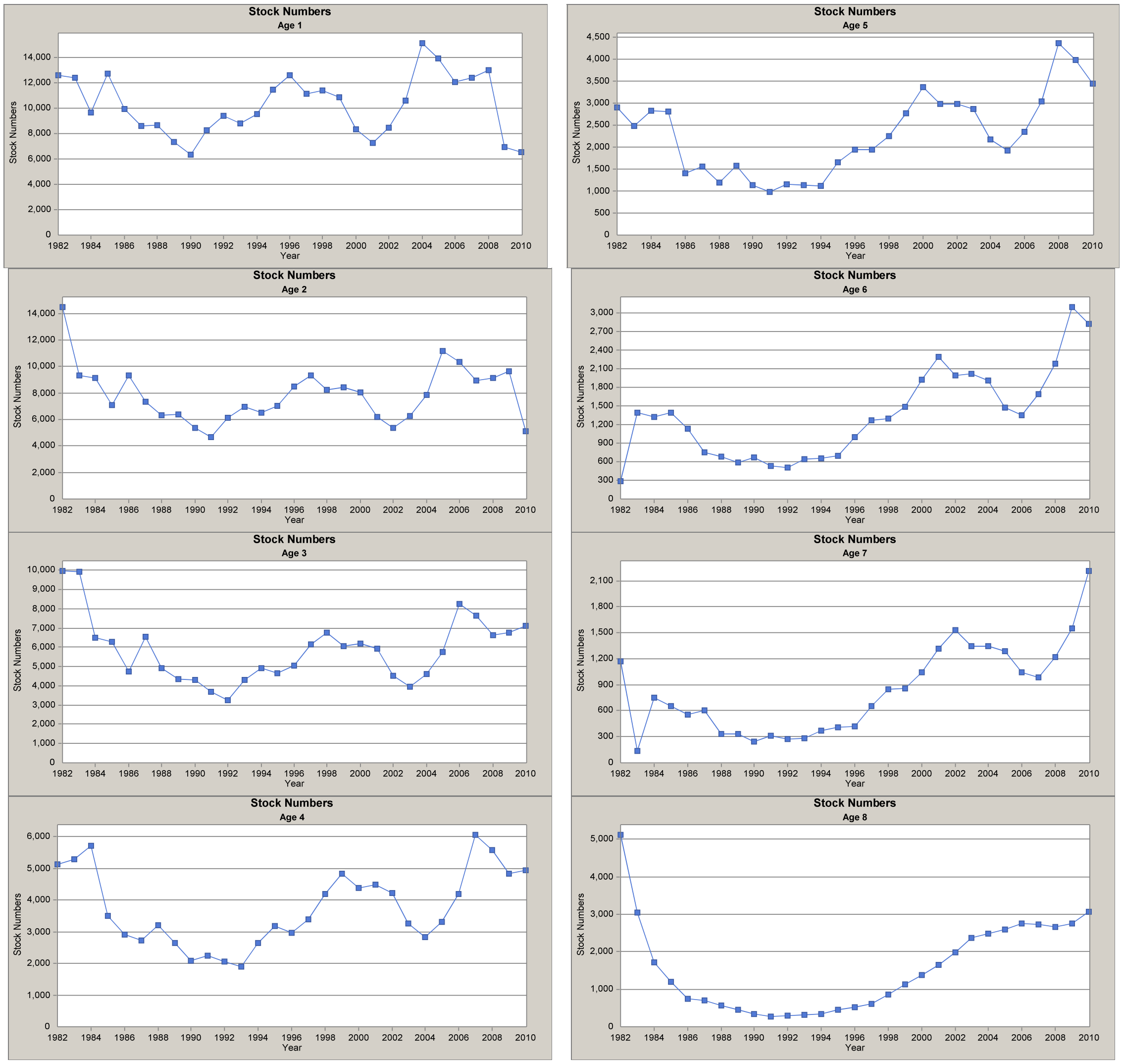
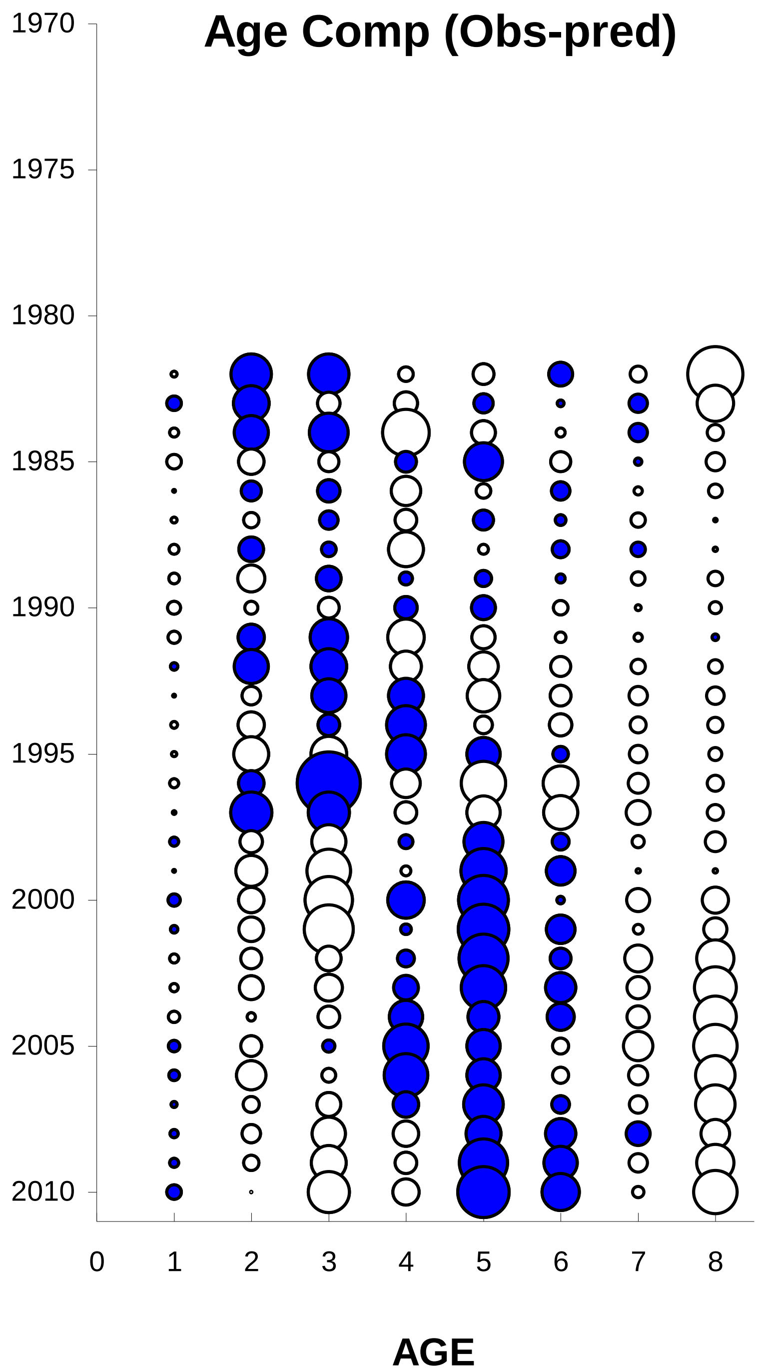


Figure C49. Estimated numbers at age from the ASAP indices at age run with a ESS weight of 50 on the catch at age composition.



Figures C50. Fit to catch at age composition with the ASAP indices at age run with a effective sample size weight of 150.

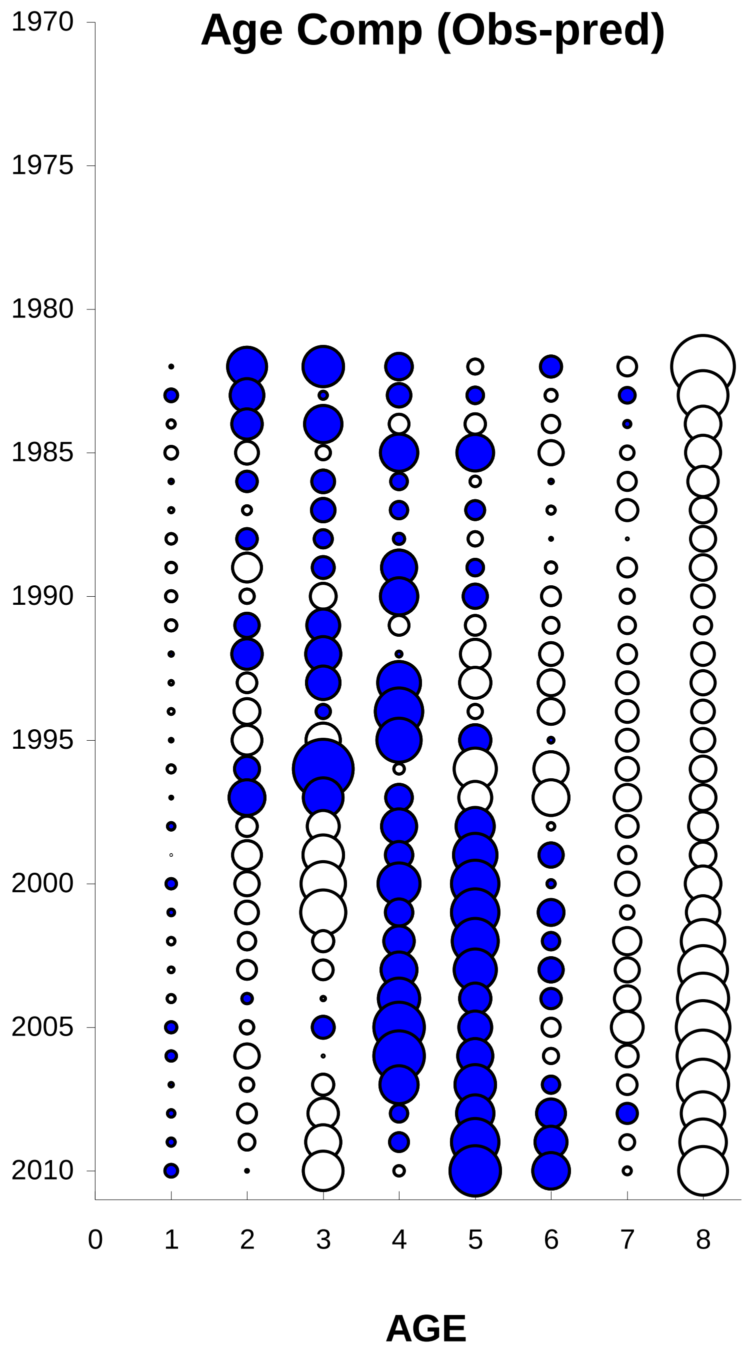


Figure C51. Fit to catch at age composition with the ASAP indices at age run with a effective sample size weight of 50.

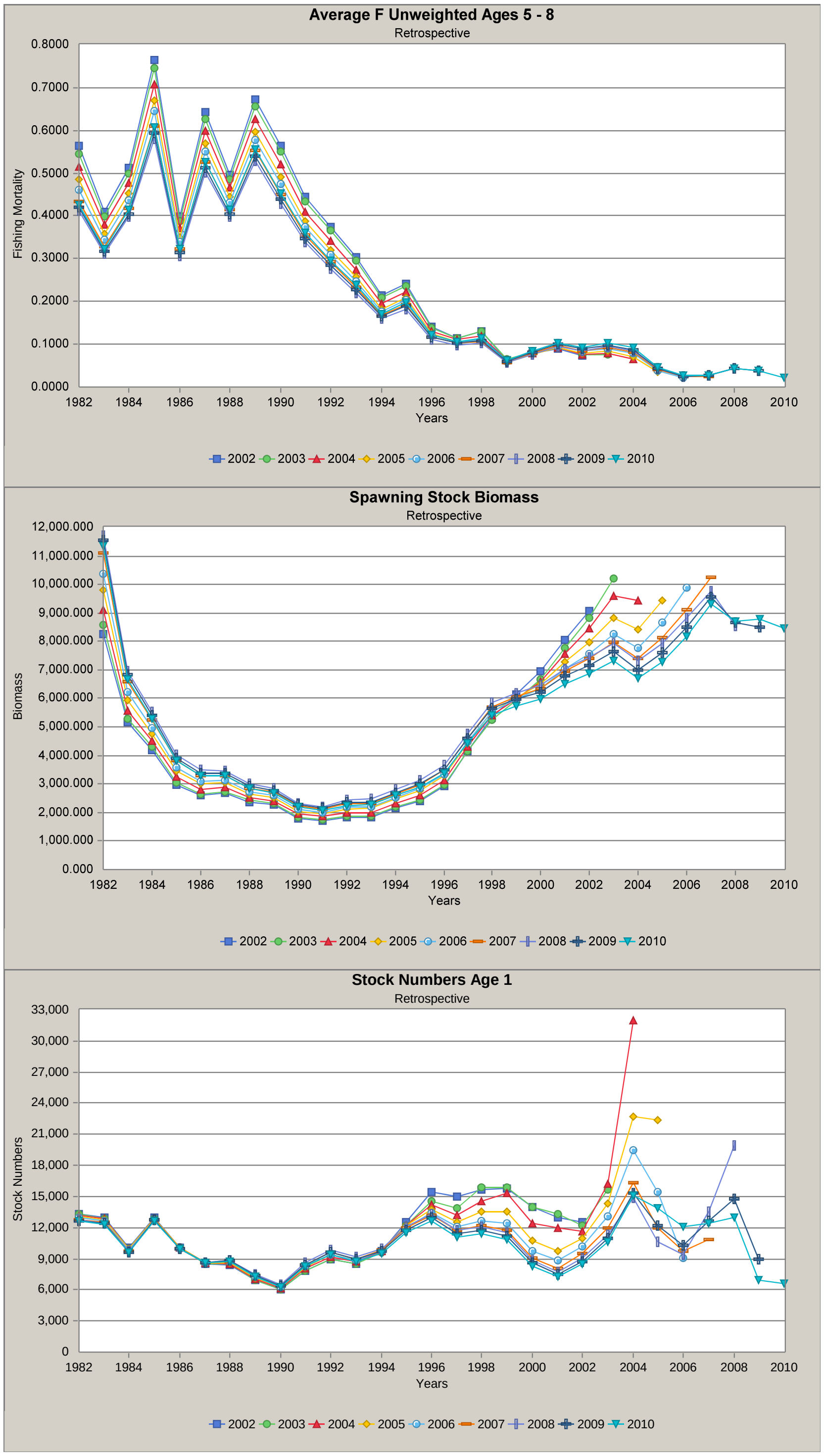
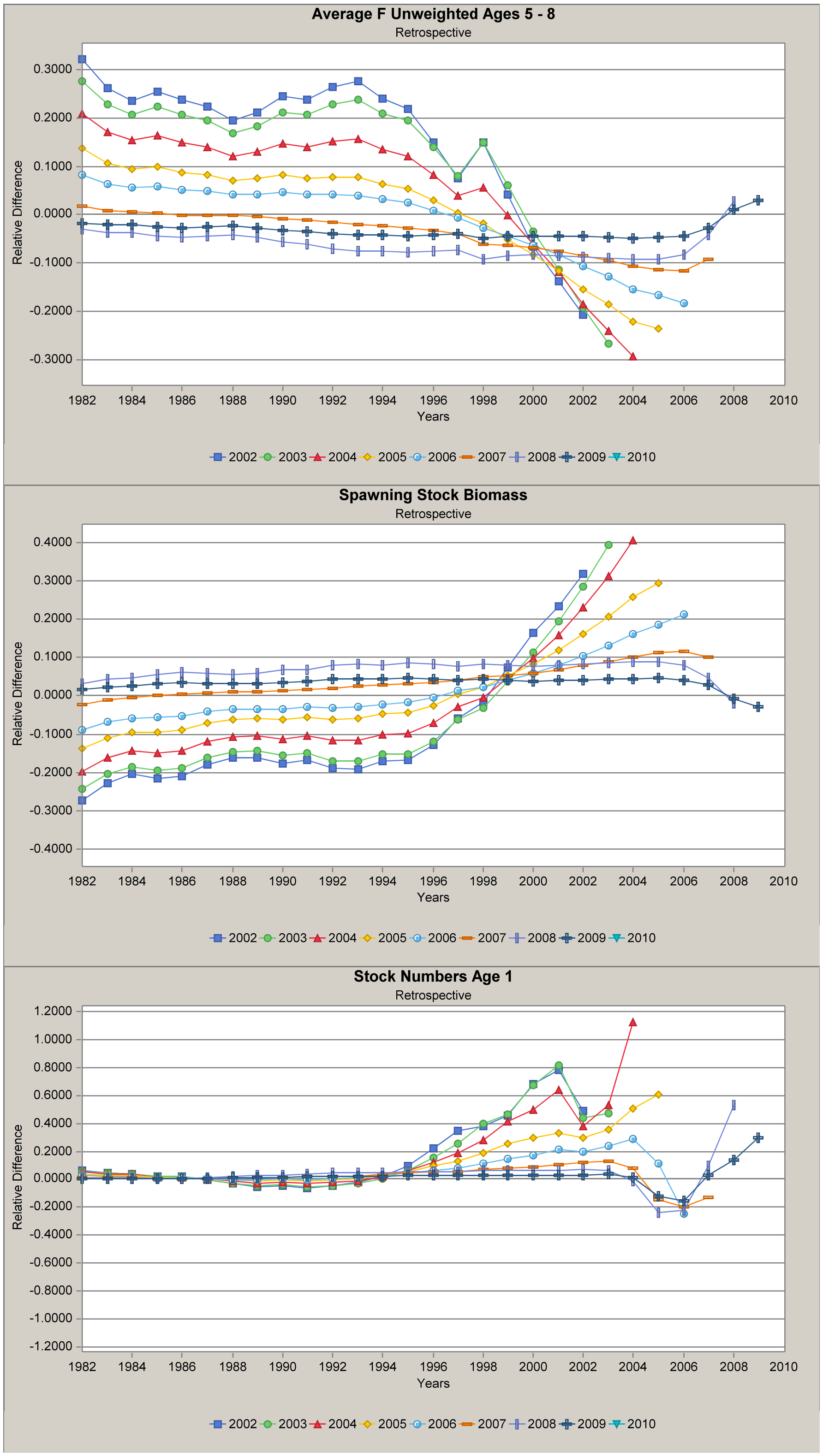
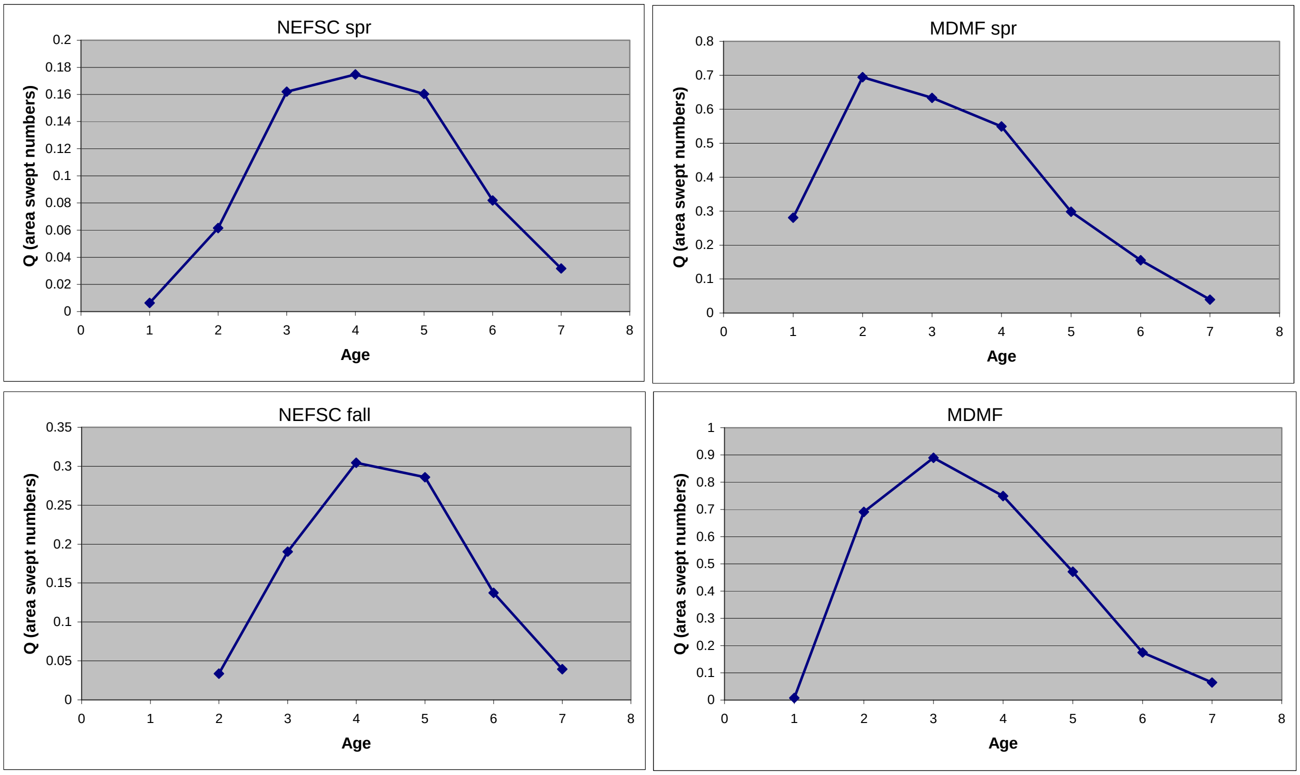


Figure C52. Retrospective pattern from ASAP indices at age run with an effective sample size weight of 50 on the catch at age composition.



Figures C53. Relative retrospective pattern from ASAP indices at age run with an effective sample size weight of 50 on the catch at age composition.



Figures C54. Selectivity from ASAP indices at age run with an effective sample size weight of 50 on the catch at age composition.

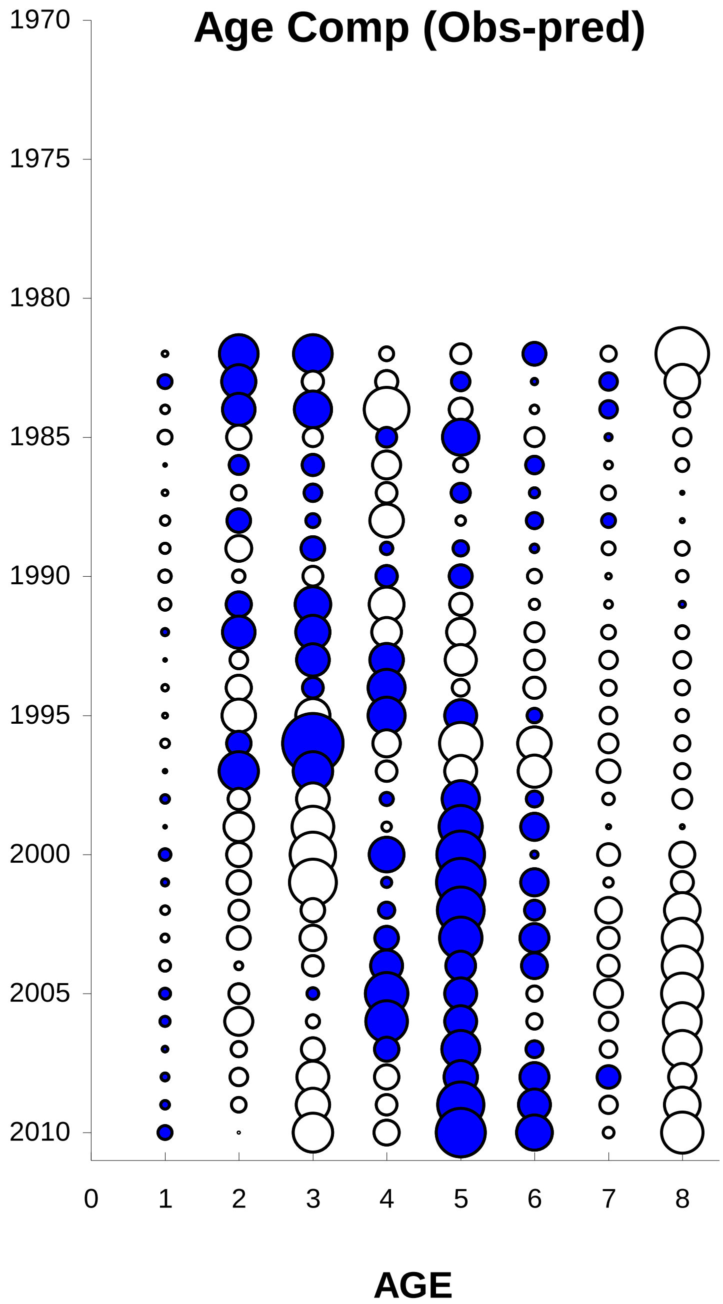


Figure C55. Fit to catch at age composition with the ASAP multi run with a effective sample size weight of 50.

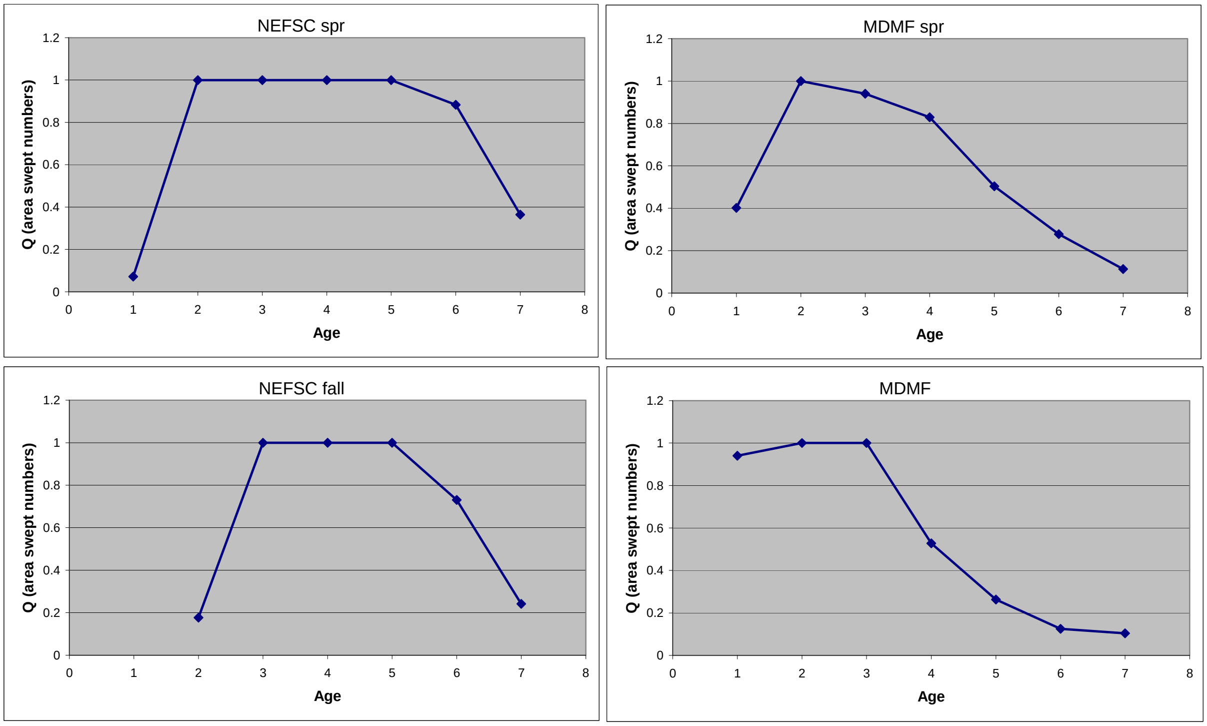


Figure C56. Selectivity from ASAP multi run with an effective sample size weight of 50 on the catch at age composition.

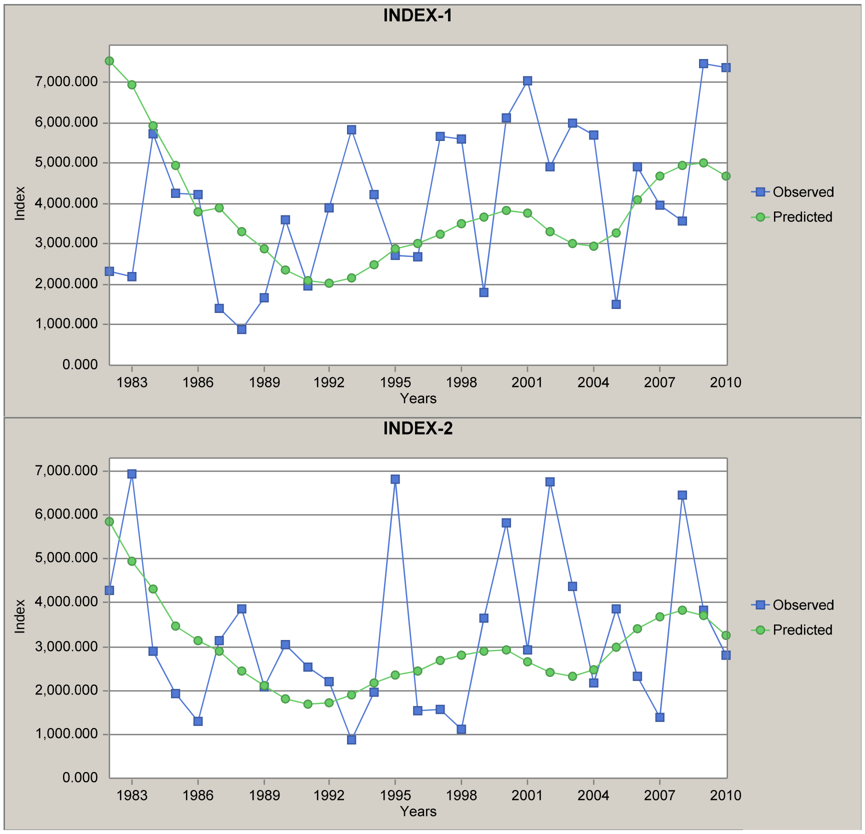
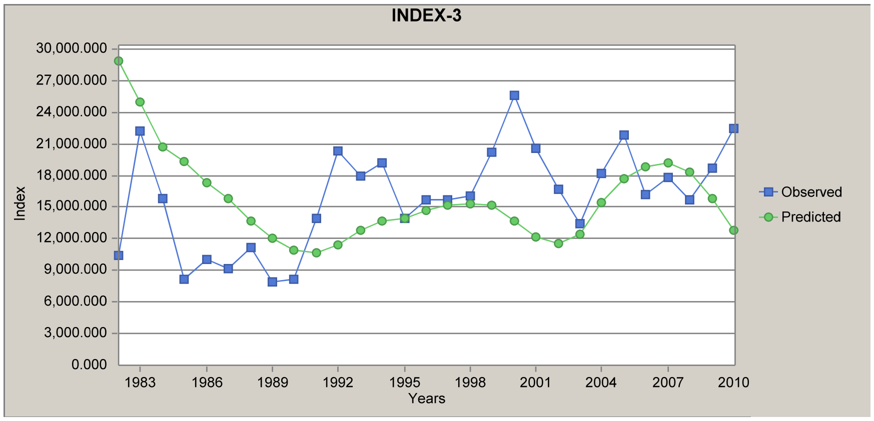


Figure C57. Fit to aggregate indices from the ASAP multi run with a effective sample size weight of 50.



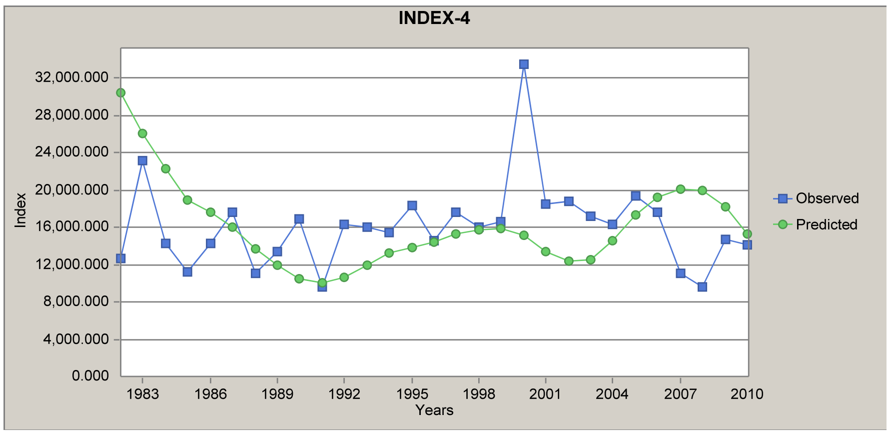
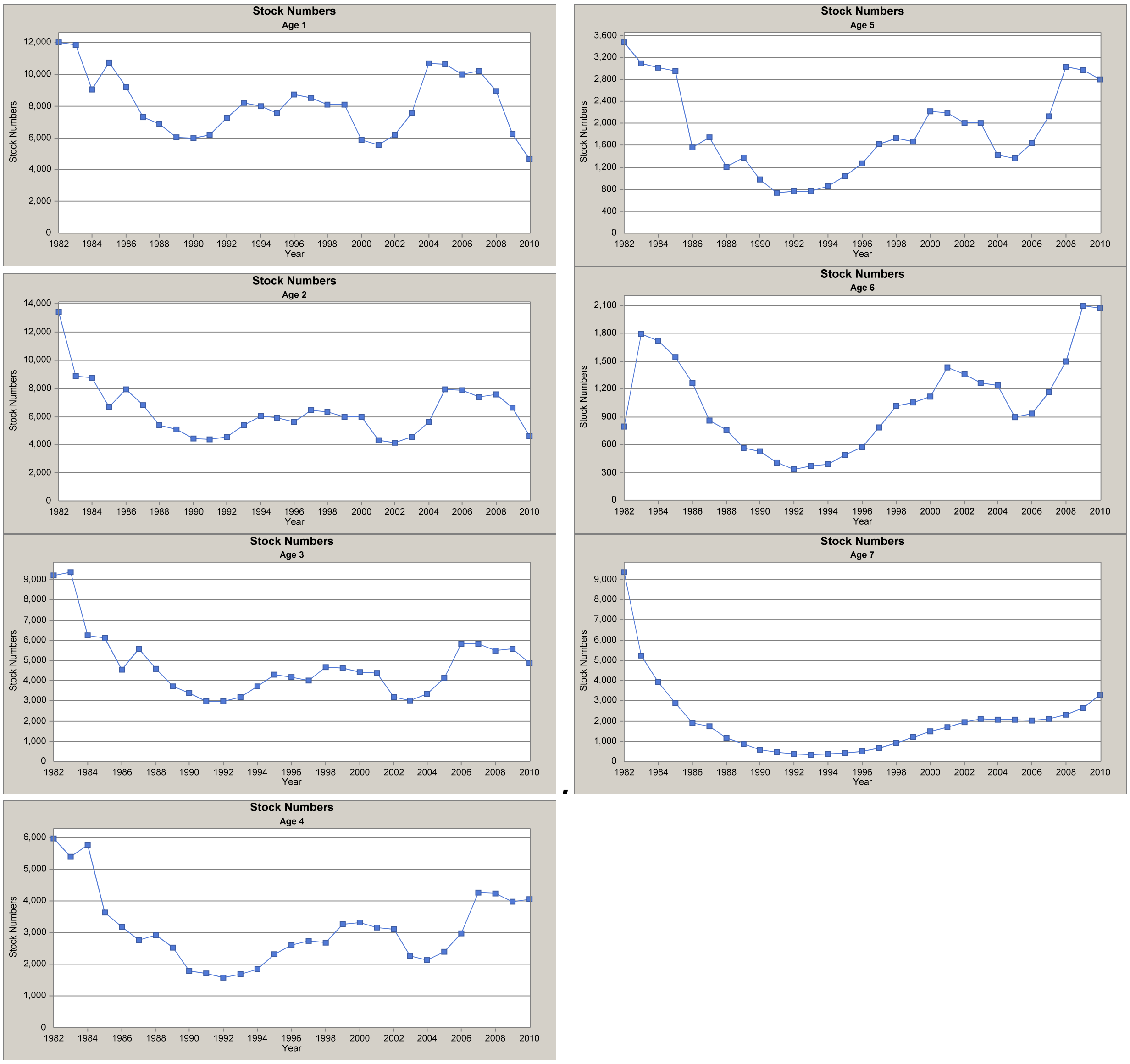


Figure C57. Cont.



Figures C58. Estimated numbers at age from the ASAP multi run with a ESS weight of 50 on the catch at age composition.

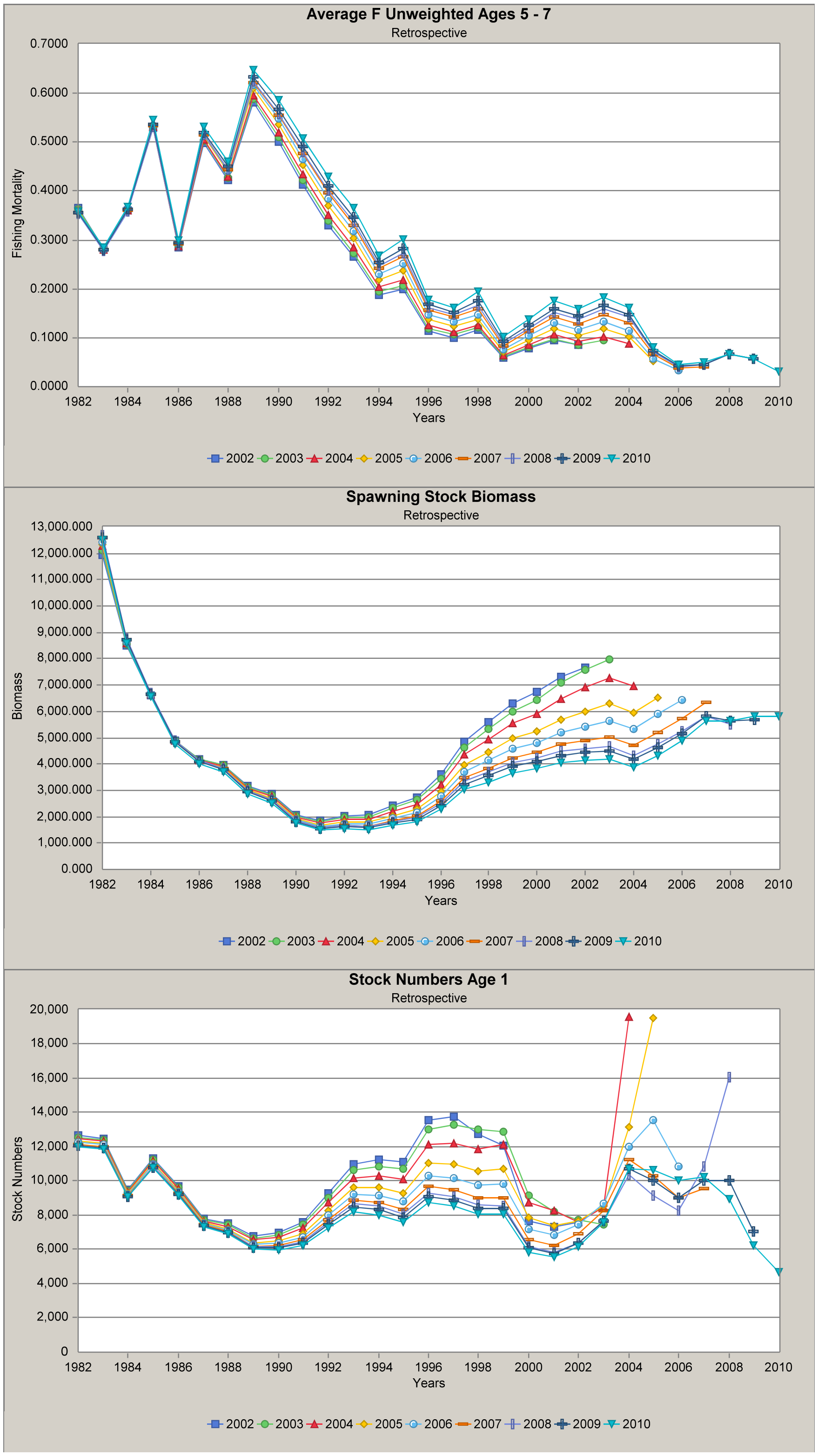
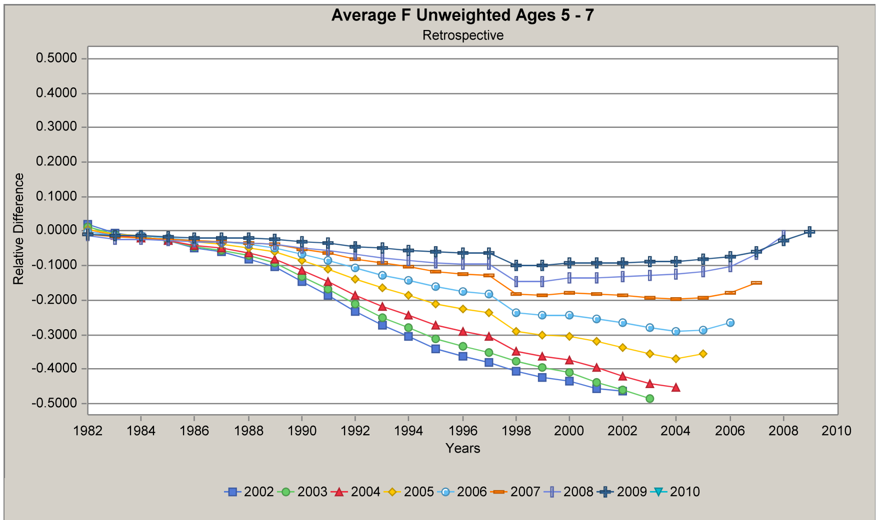
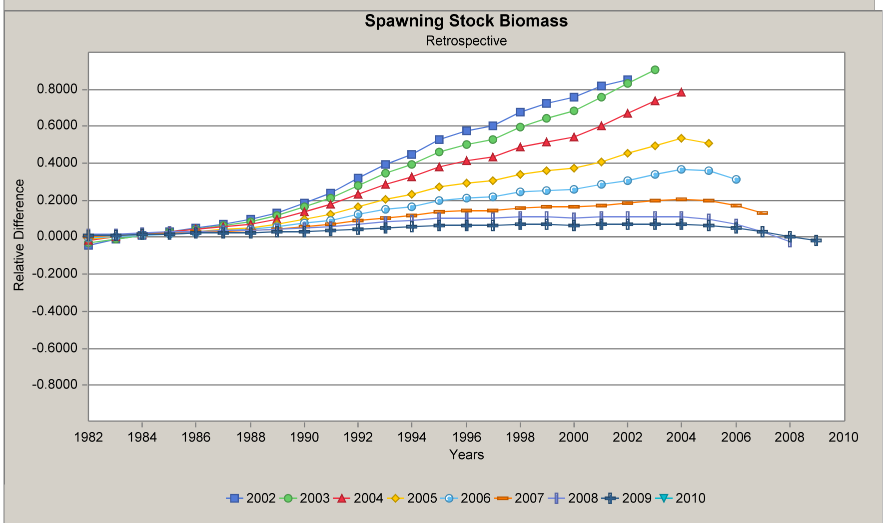
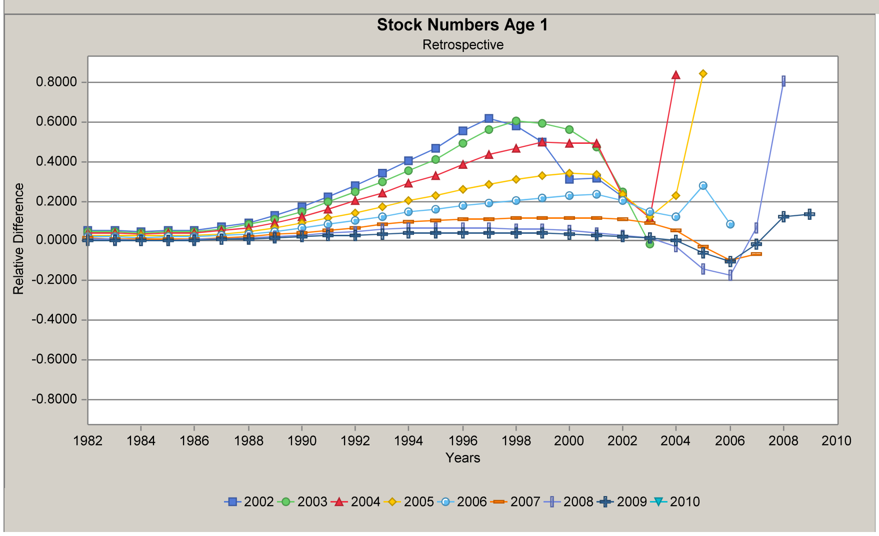


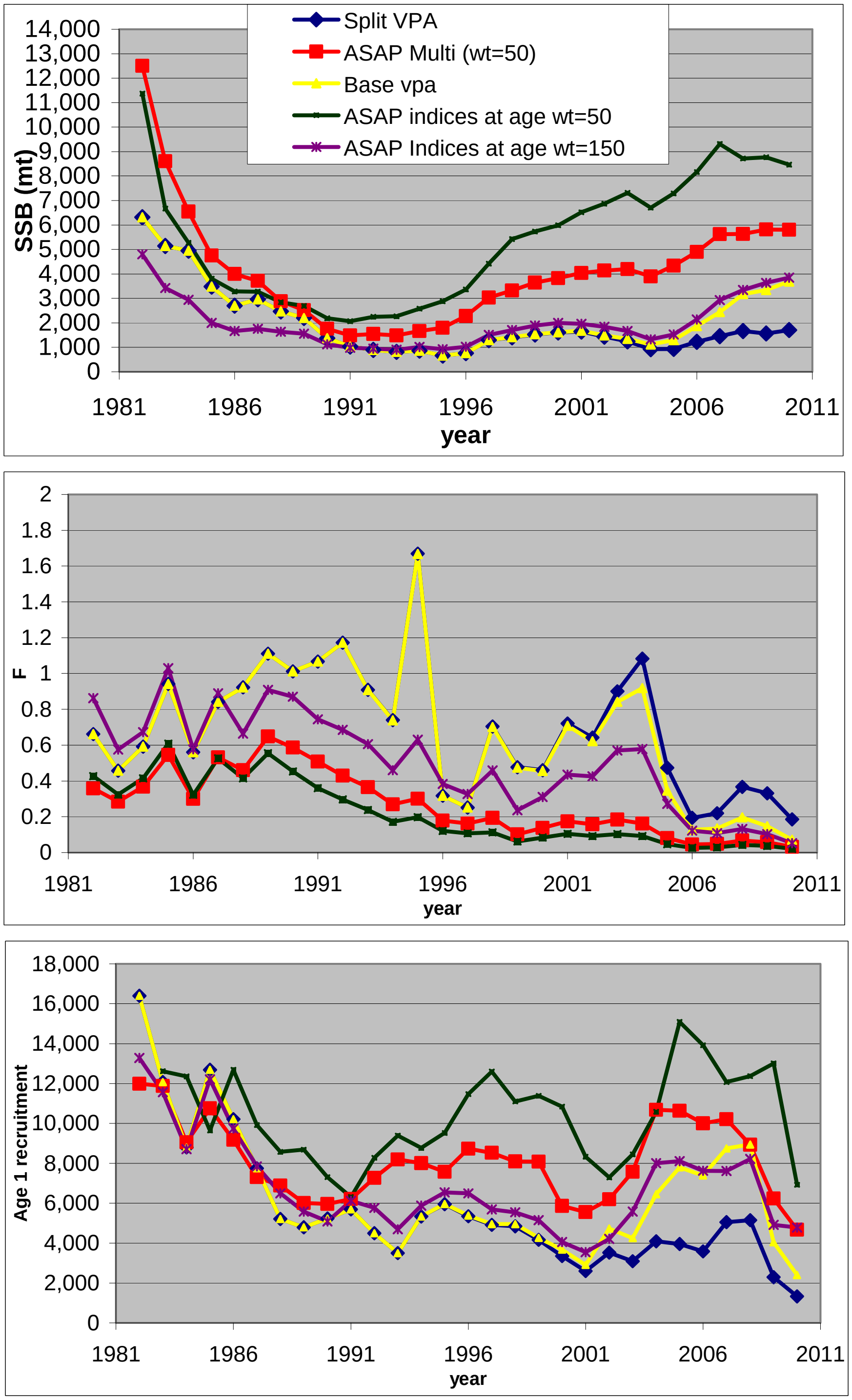
Figure C59. Retrospective pattern from ASAP multi run with an effective sample size weight of 50 on the catch at age composition.







Figures C60. Relative retrospective pattern from ASAP multi run with an effective sample size weight of 50 on the catch at age composition.



Figures C61. Comparison of different VPA and ASAP model runs for SSB, F and recruitment.

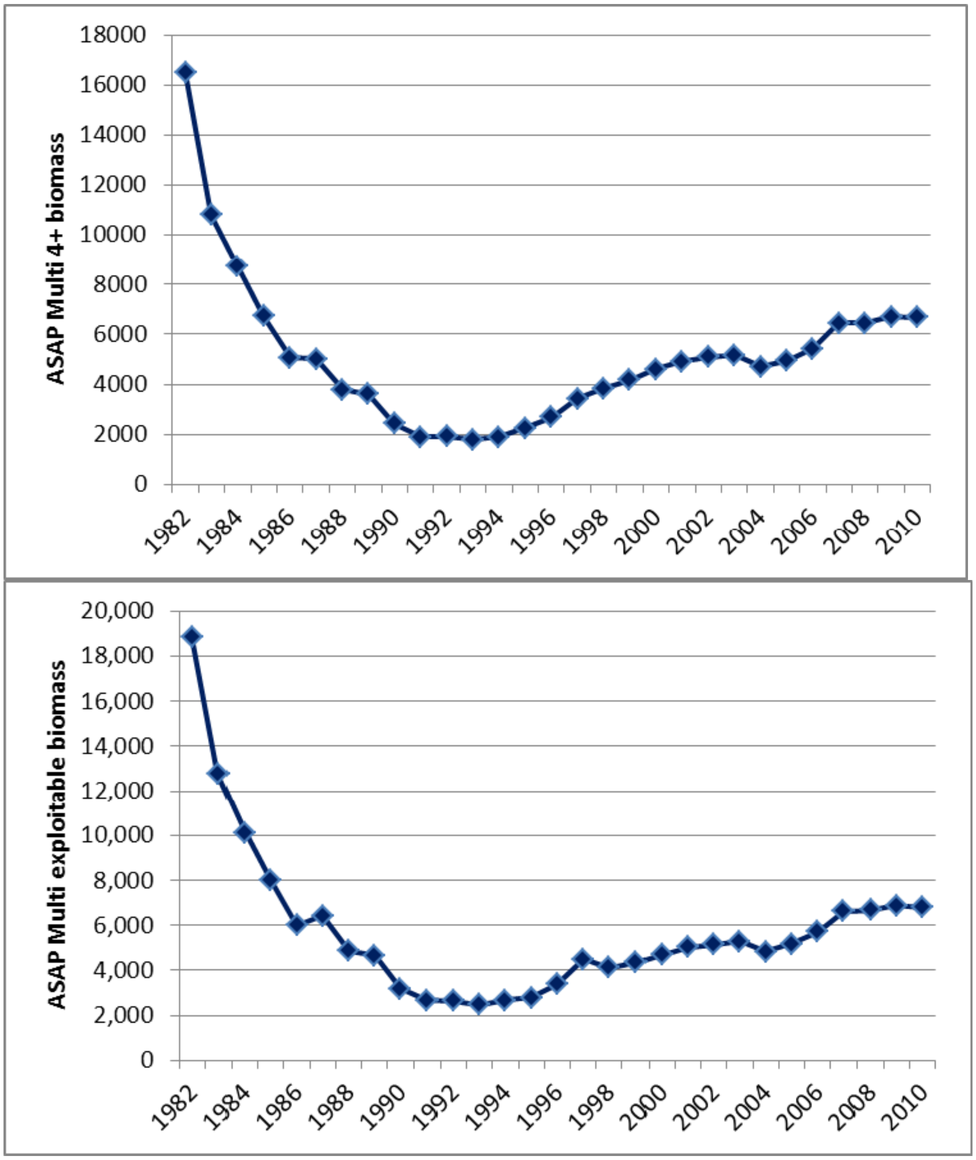
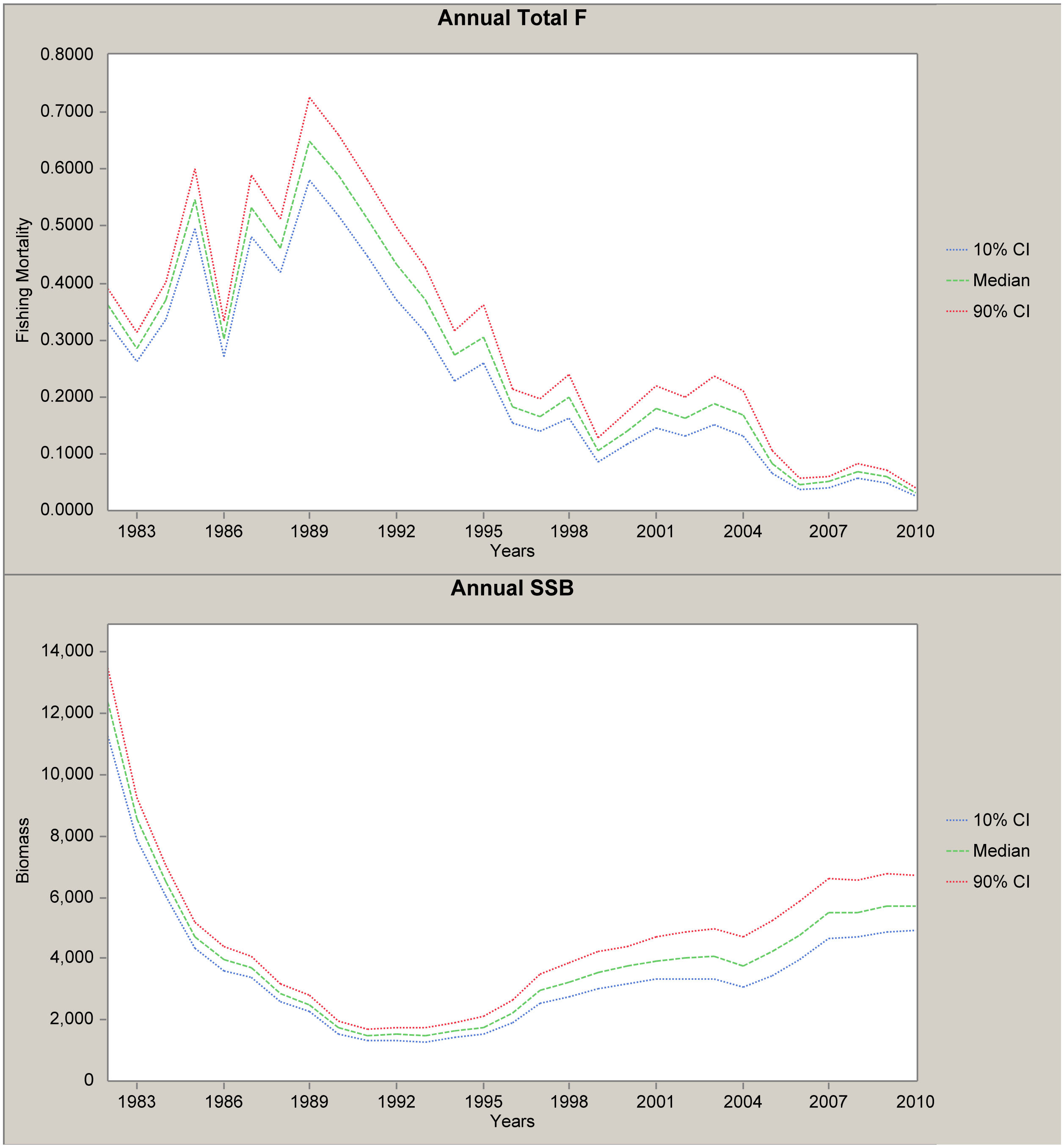


Figure C62. Estimated 4+ biomass and exploitable biomass from the preferred ASAP multi run.



Figures C63. Estimated fishing mortality and SSB with 80% confidence intervals from 1000 mcmc iterations for the preferred ASAP multi run.

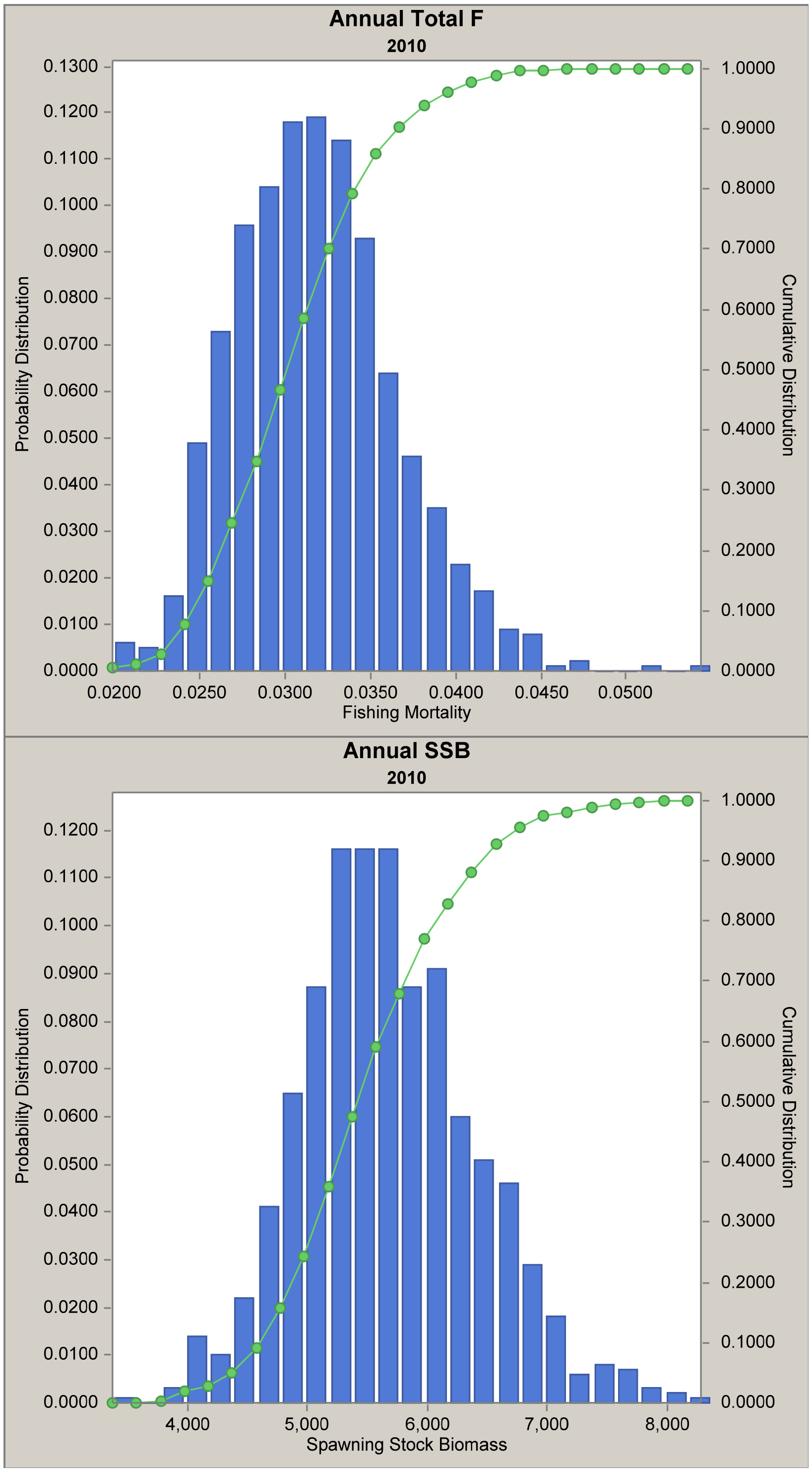


Figure C64. Estimated fishing mortality and SSB from 1000 mcmc iterations for the preferred ASAP multi run for 2010.

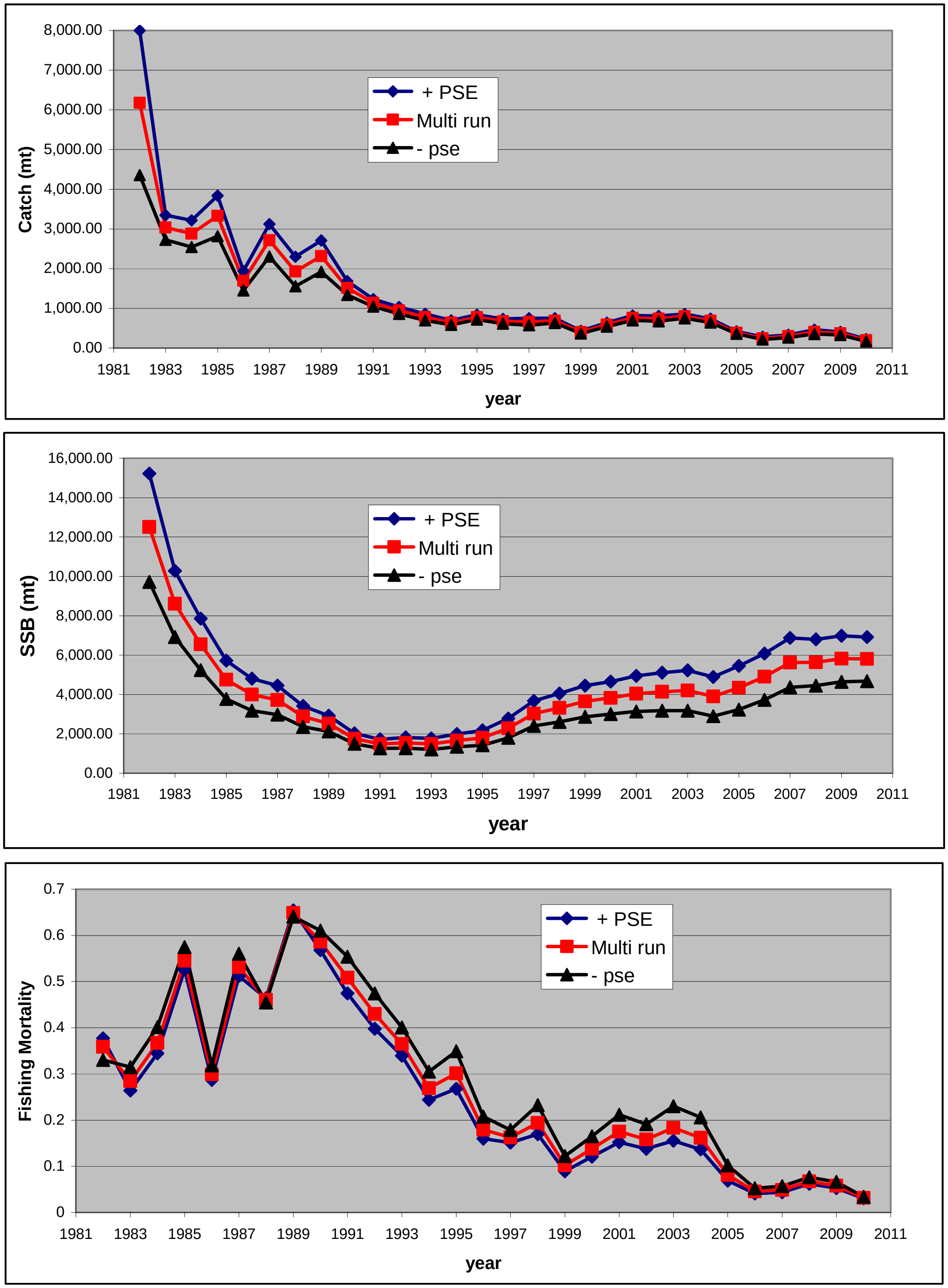


Figure C65. Assumed catch (top), SSB (middle) and fishing mortality (bottom) for the final ASAP multi model, the final multi model with the PSE added to the catch, and the PSE subtracted from the catch. This analysis was done to address TOR 4.

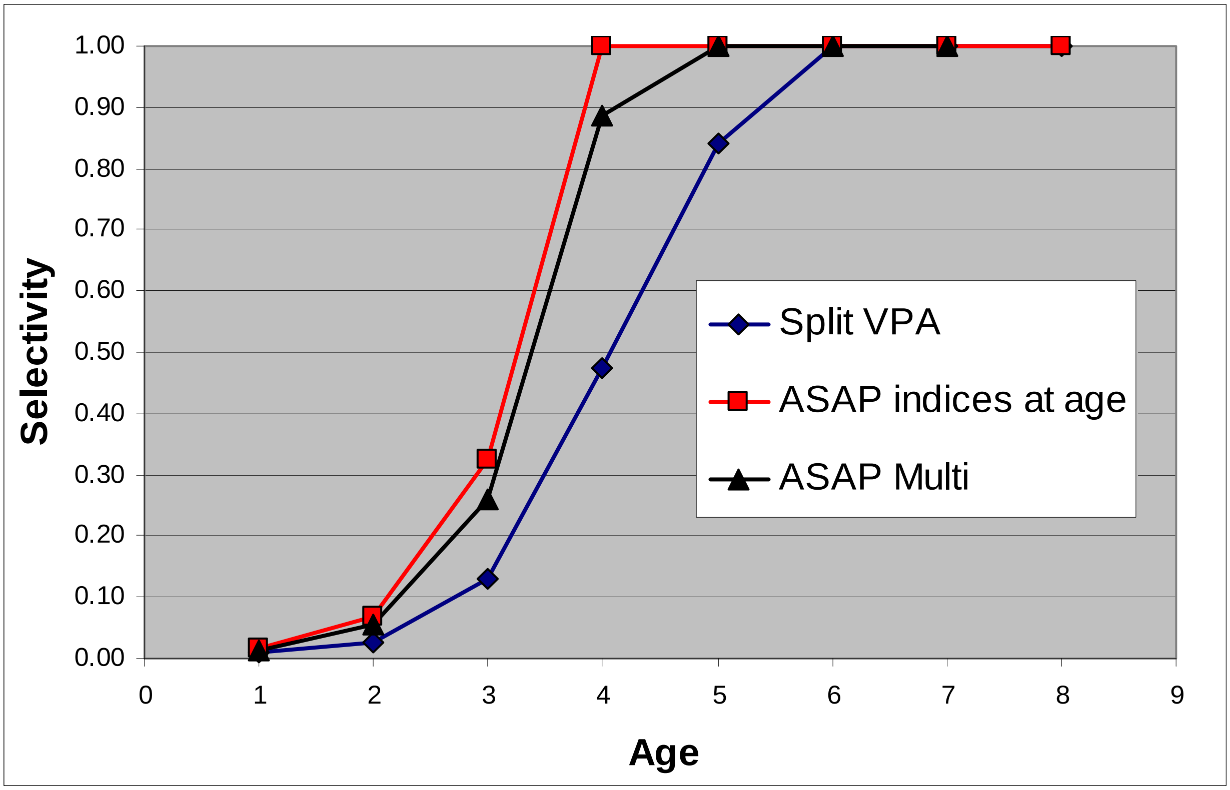


Figure C66. Comparison of estimated selectivity used for the estimation of biological reference point for the split VPA, ASAP indices at age and multi models.

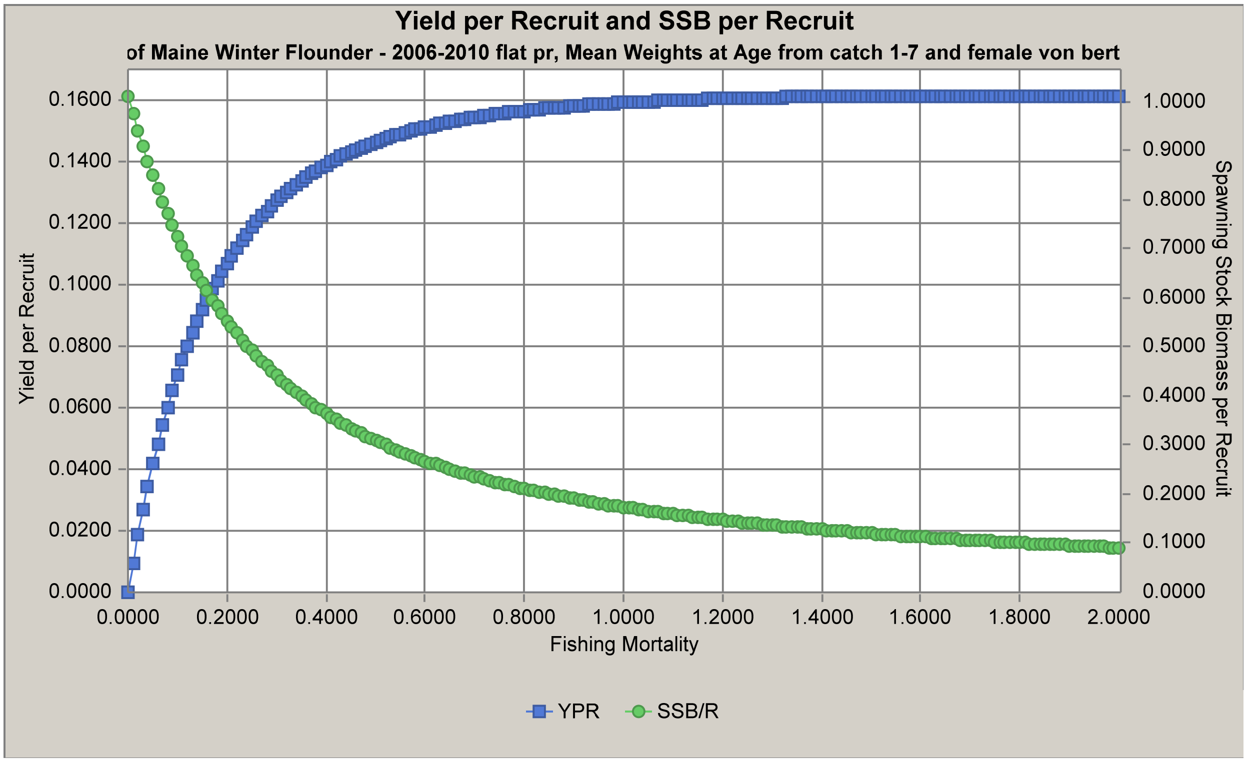
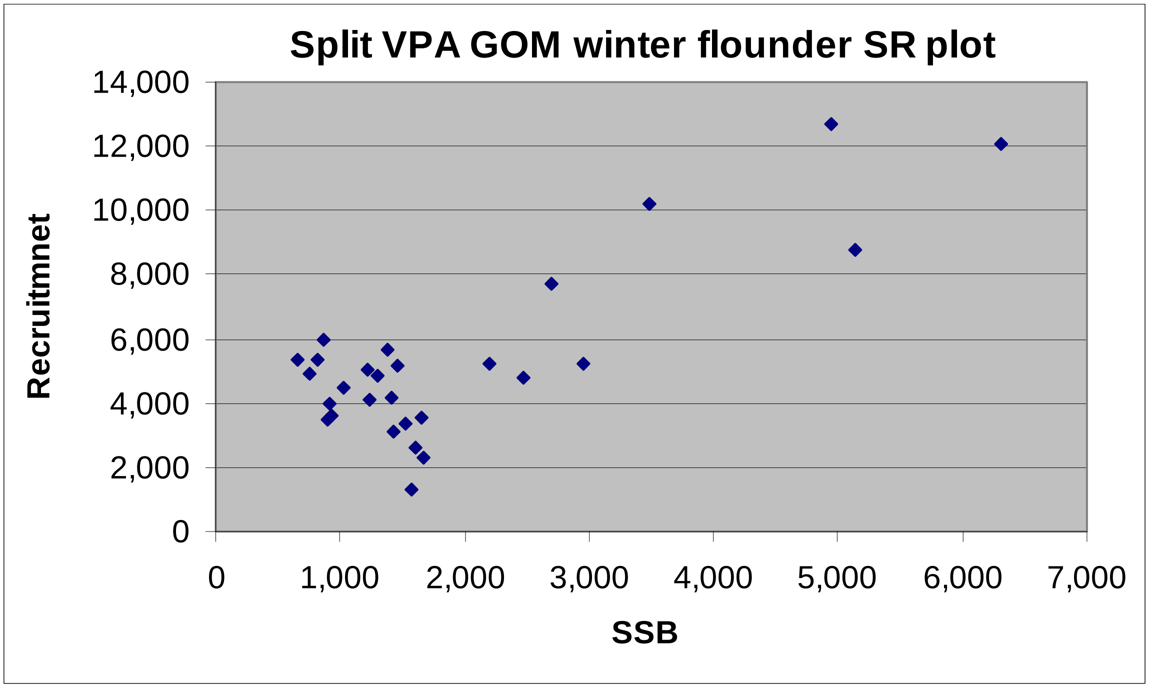


Figure C67. Yield per recruit analysis from the ASAP multi run.



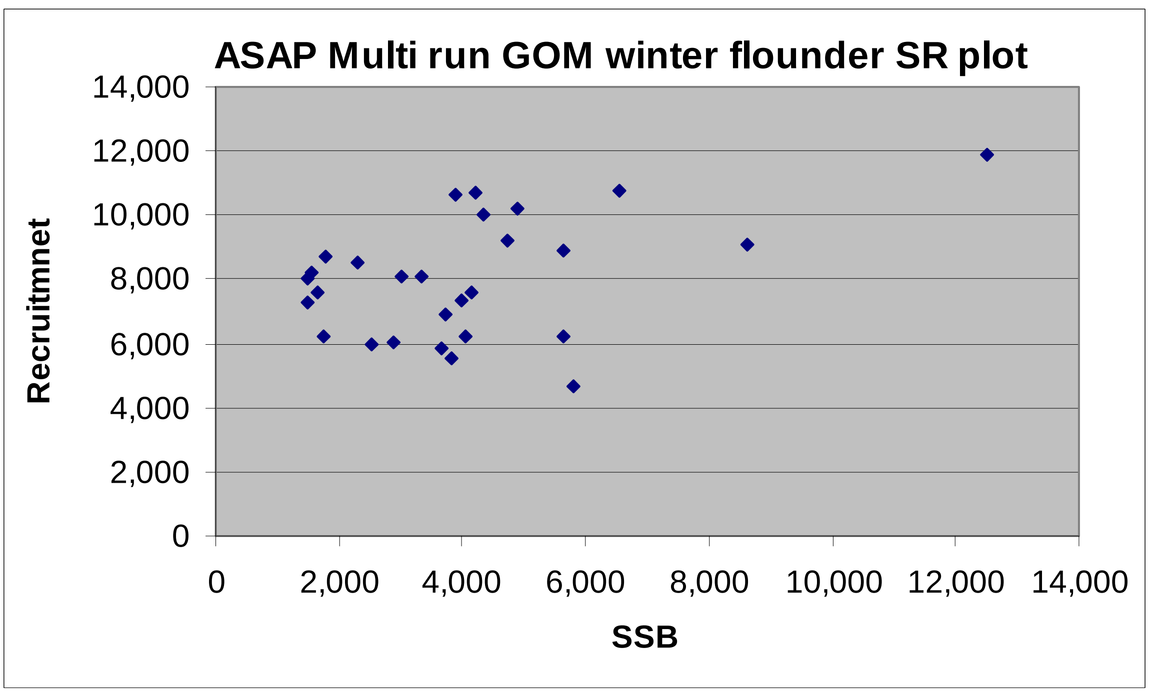
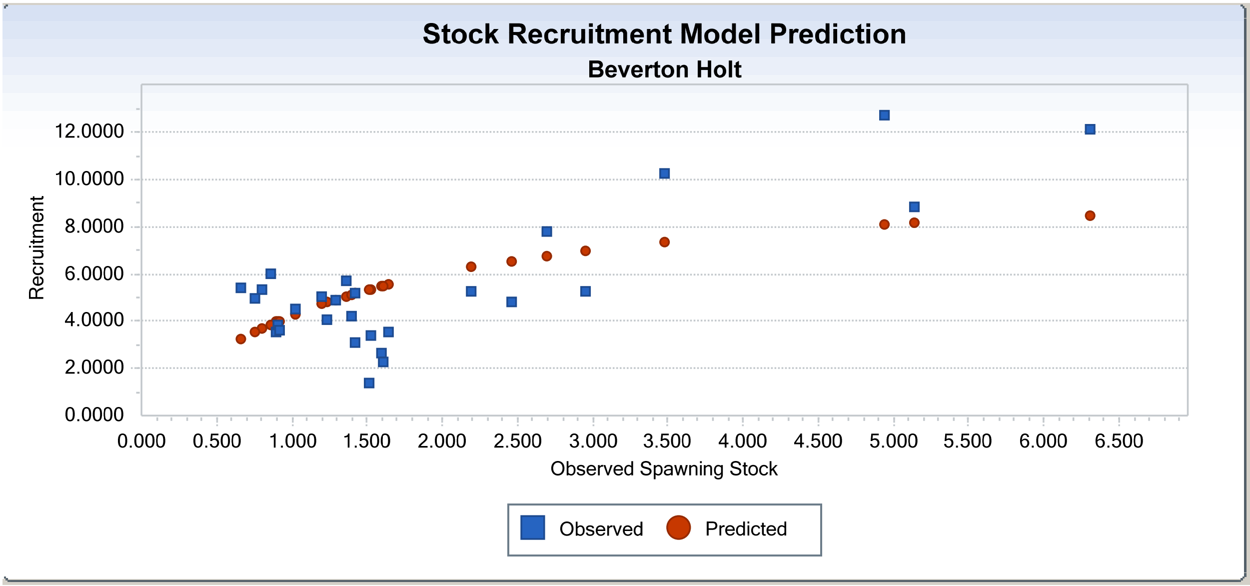


Figure C68. Stock recruit plots from the split VPA and ASAP multi runs.



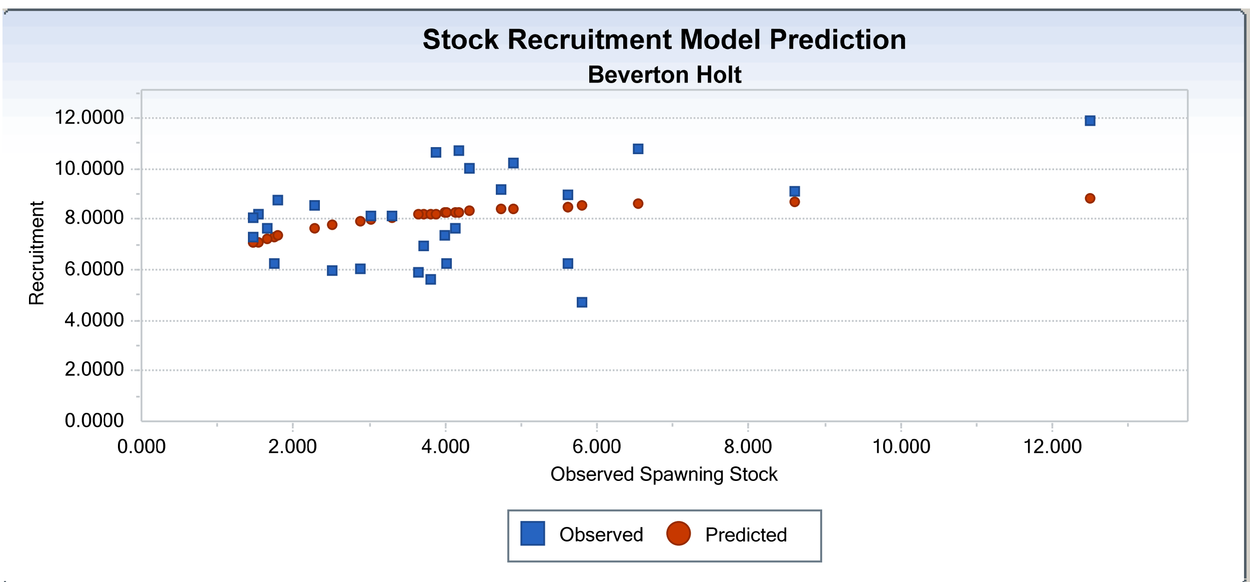


Figure C69. The estimated stock recruit curves from the split VPA and ASAP multi runs with a prior on steepness.

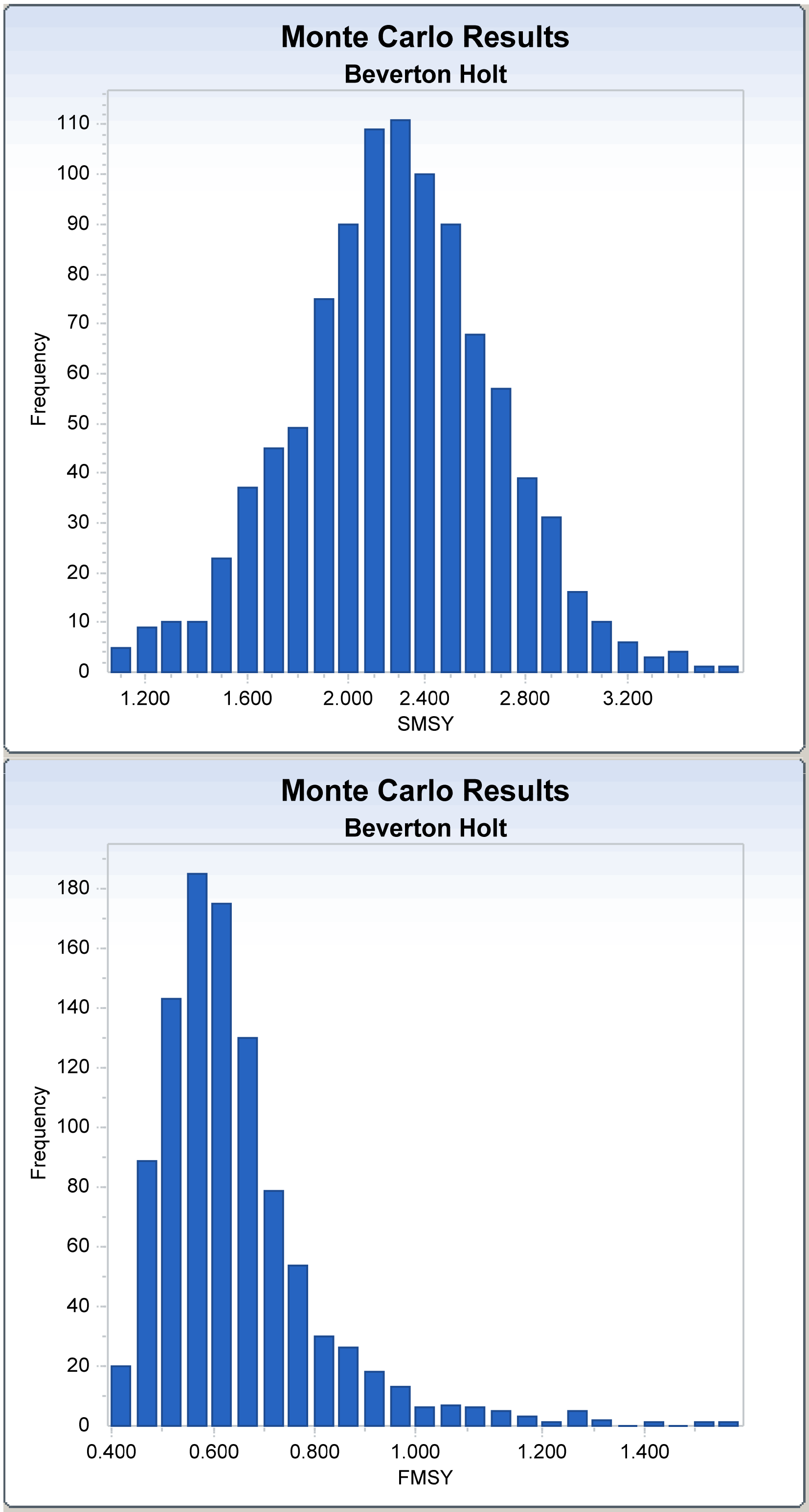


Figure C70. Estimated SSBmsy and Fmsy distribution from 1000 mcmc iterations for the preferred ASAP multi run with a prior on steepness.

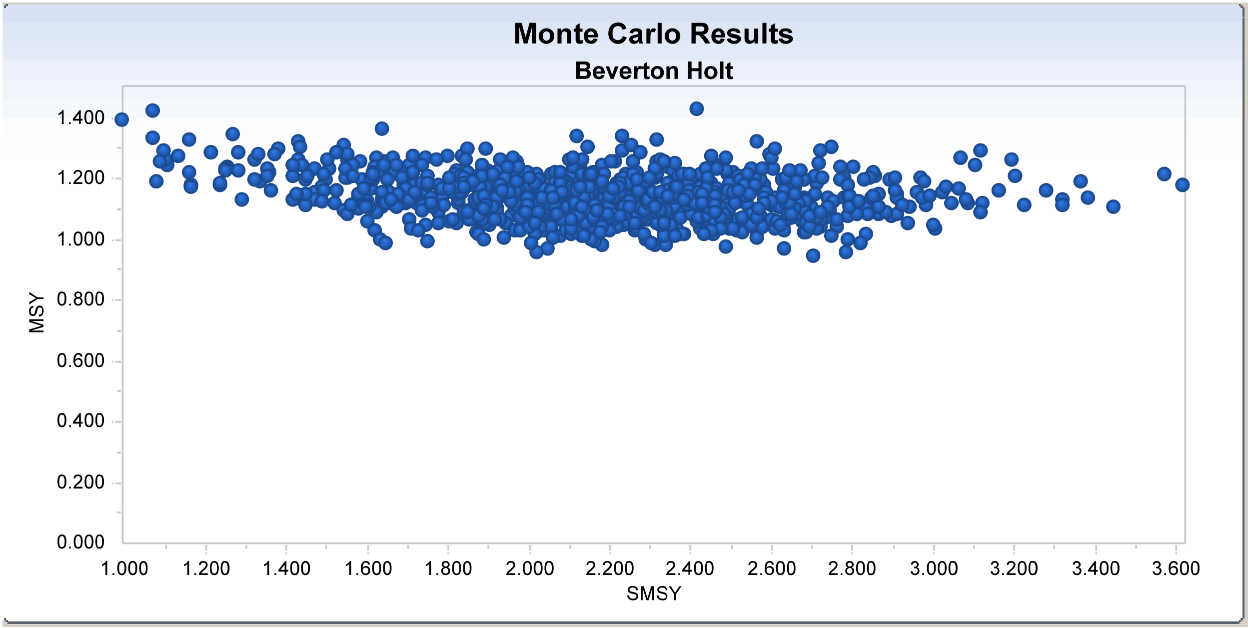
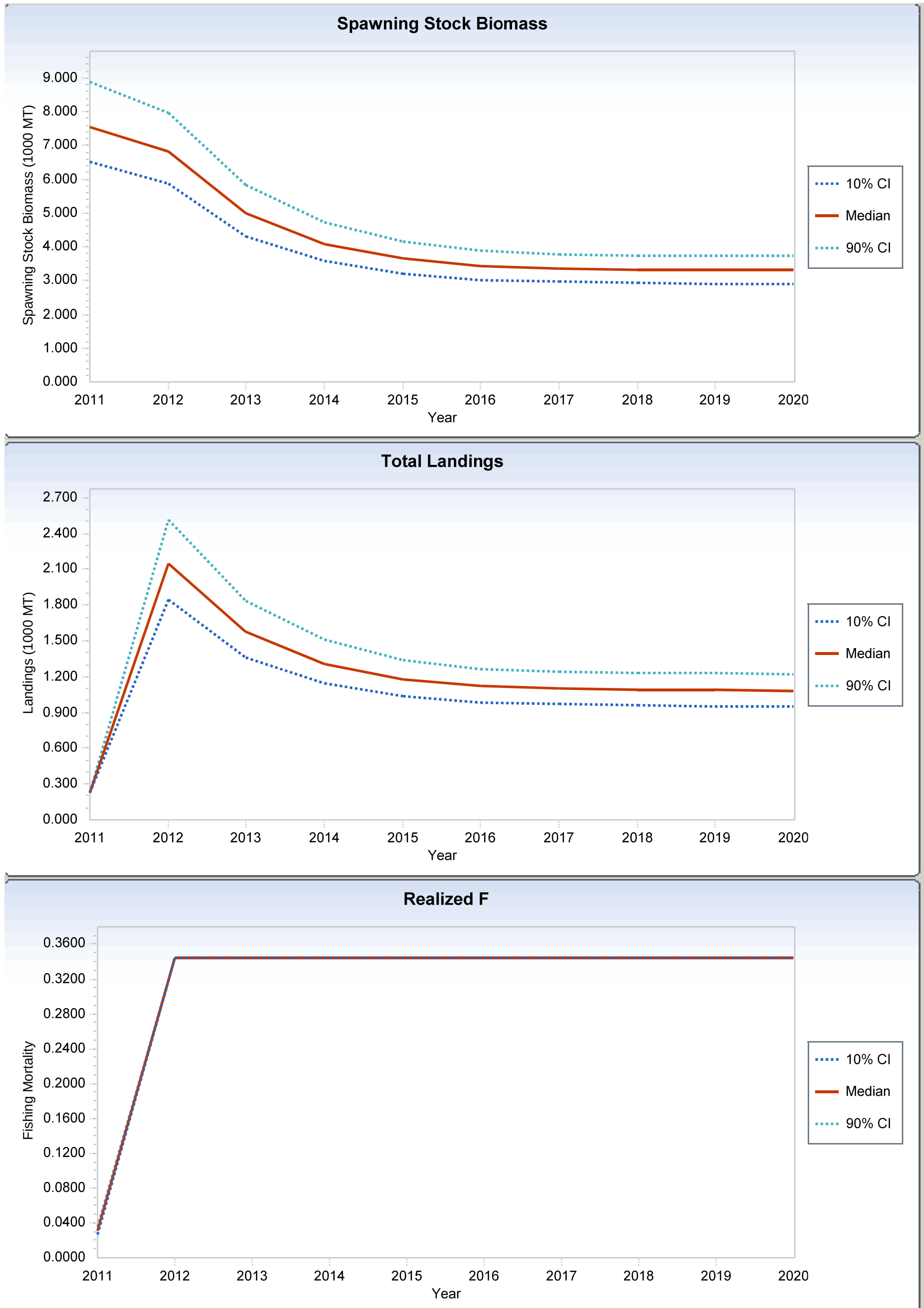


Figure C71. Variation of MSY with SSBmsy estimates from 1000 mcmc iterations for the preferred ASAP multi run with a prior on steepness.

Figures C72. SSB, catch, and fishing mortality assuming catch is 230 mt (ACL) in 2011 and the Fmsy proxy of F40% = 0.43 from 2012 to 2020 from the split VPA.

Figures C73. SSB, catch, and fishing mortality assuming catch is 230 mt (ACL) in 2011 and the 75% of the Fmsy proxy of F40% = 0.32 from 2012 to 2020 from the split VPA.



Figures C74. SSB, catch, and fishing mortality assuming catch is 230 mt (ACL) in 2011 and the Fmsy proxy of F40% = 0.34 from 2012 to 2020 from the ASAP multi run.

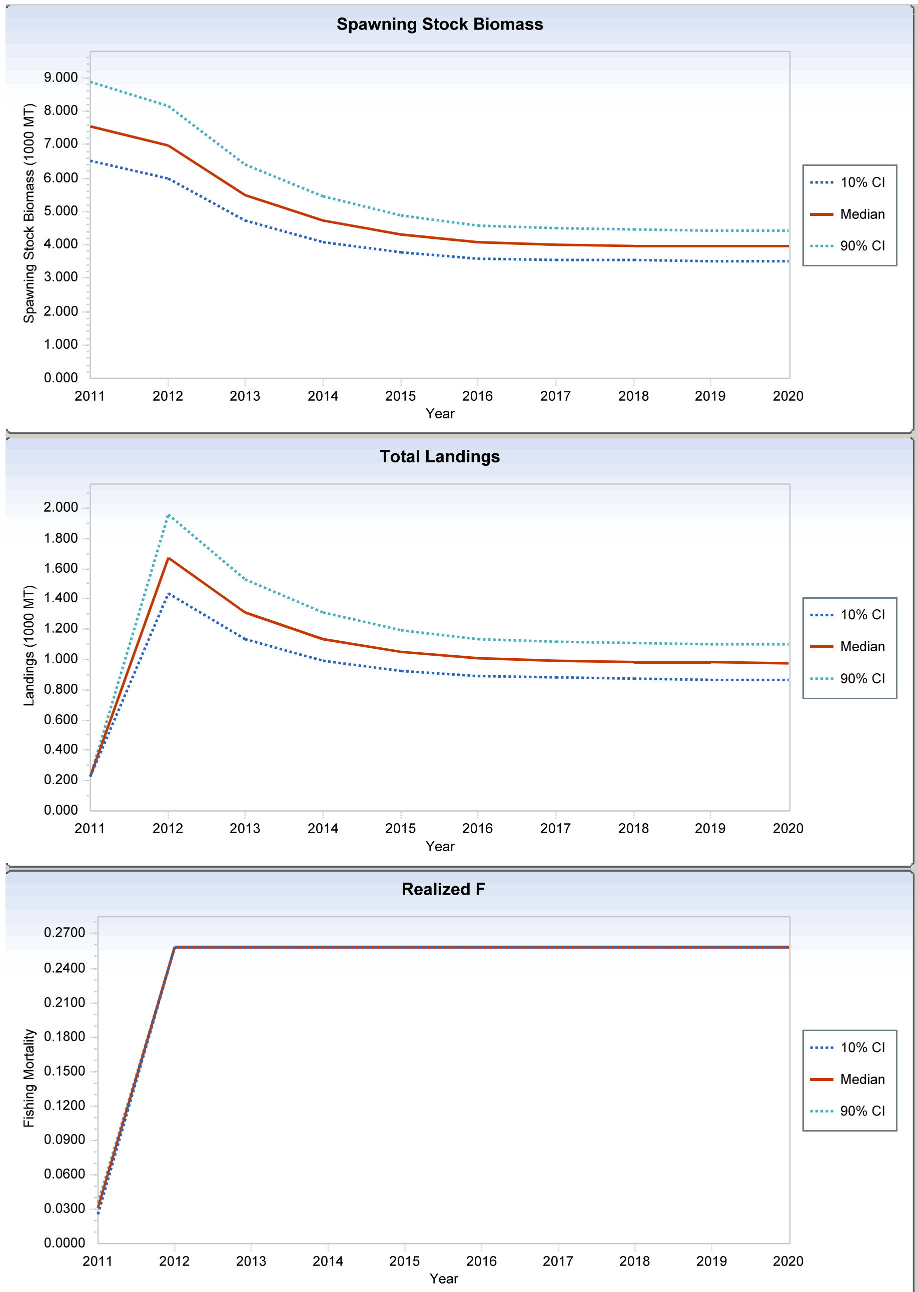


Figure C75. SSB, catch, and fishing mortality assuming catch is 230 mt (ACL) in 2011 and the 75% of the Fmsy proxy of F40% = 0.26 from 2012 to 2020 from the ASAP multi run.

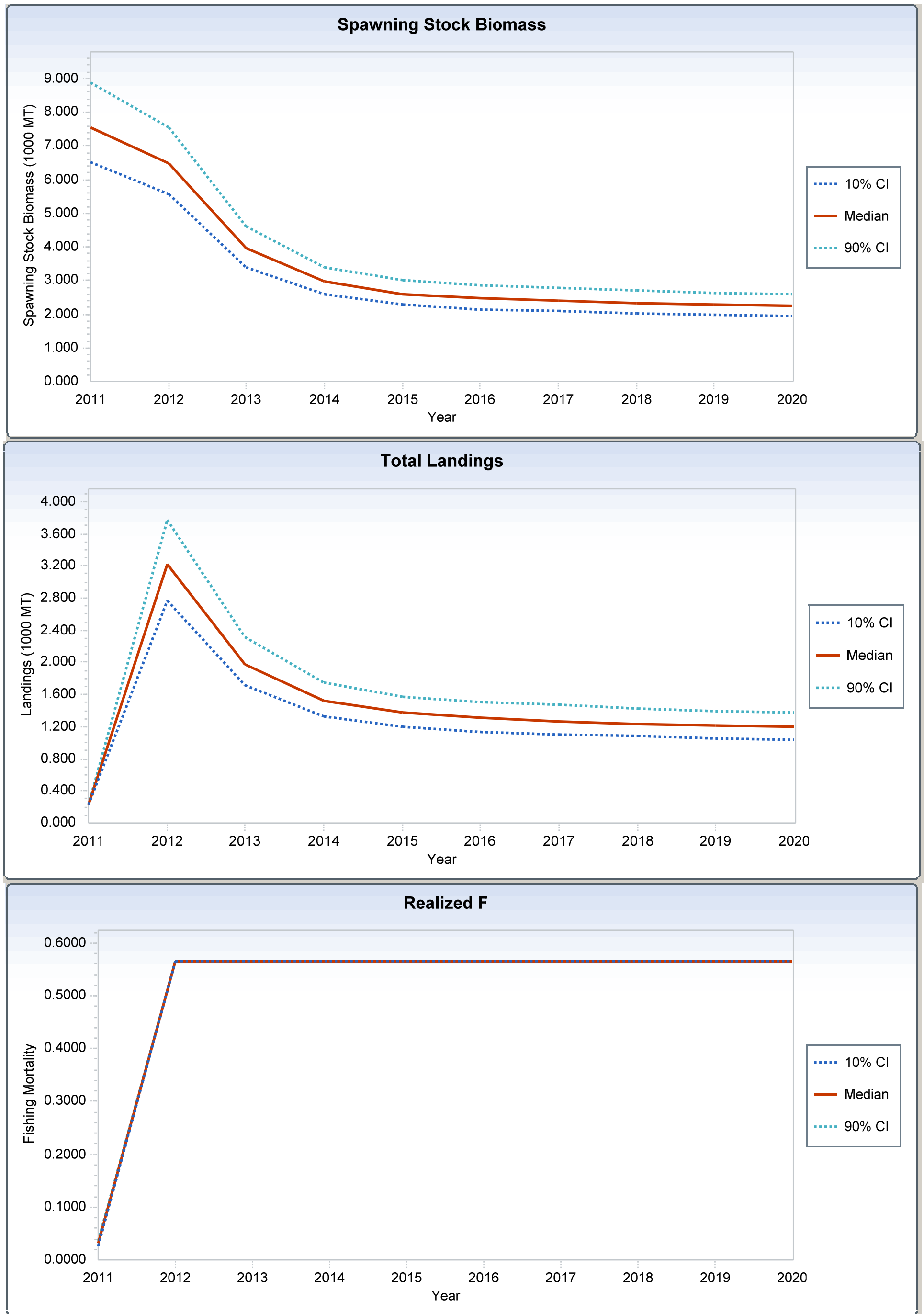
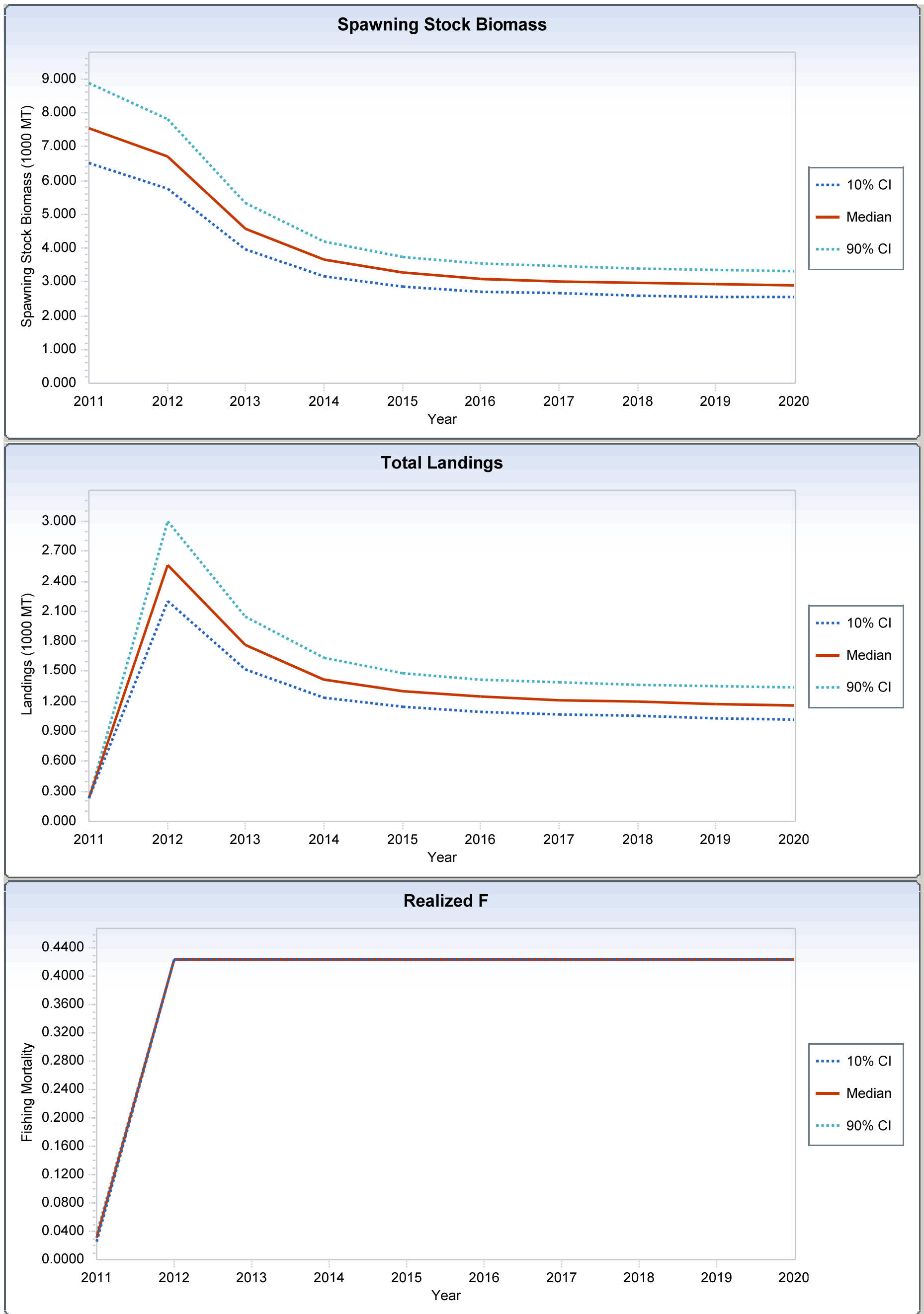


Figure C76. SSB, catch, and fishing mortality assuming catch is 230 mt (ACL) in 2011 and the stock recruit Fmsy = 0.57 from 2012 to 2020 from the ASAP multi run.



Figures C77. SSB, catch, and fishing mortality assuming catch is 230 mt (ACL) in 2011 and the 75% of the stock recruit Fmsy = 0.43 from 2012 to 2020 from the ASAP multi run.

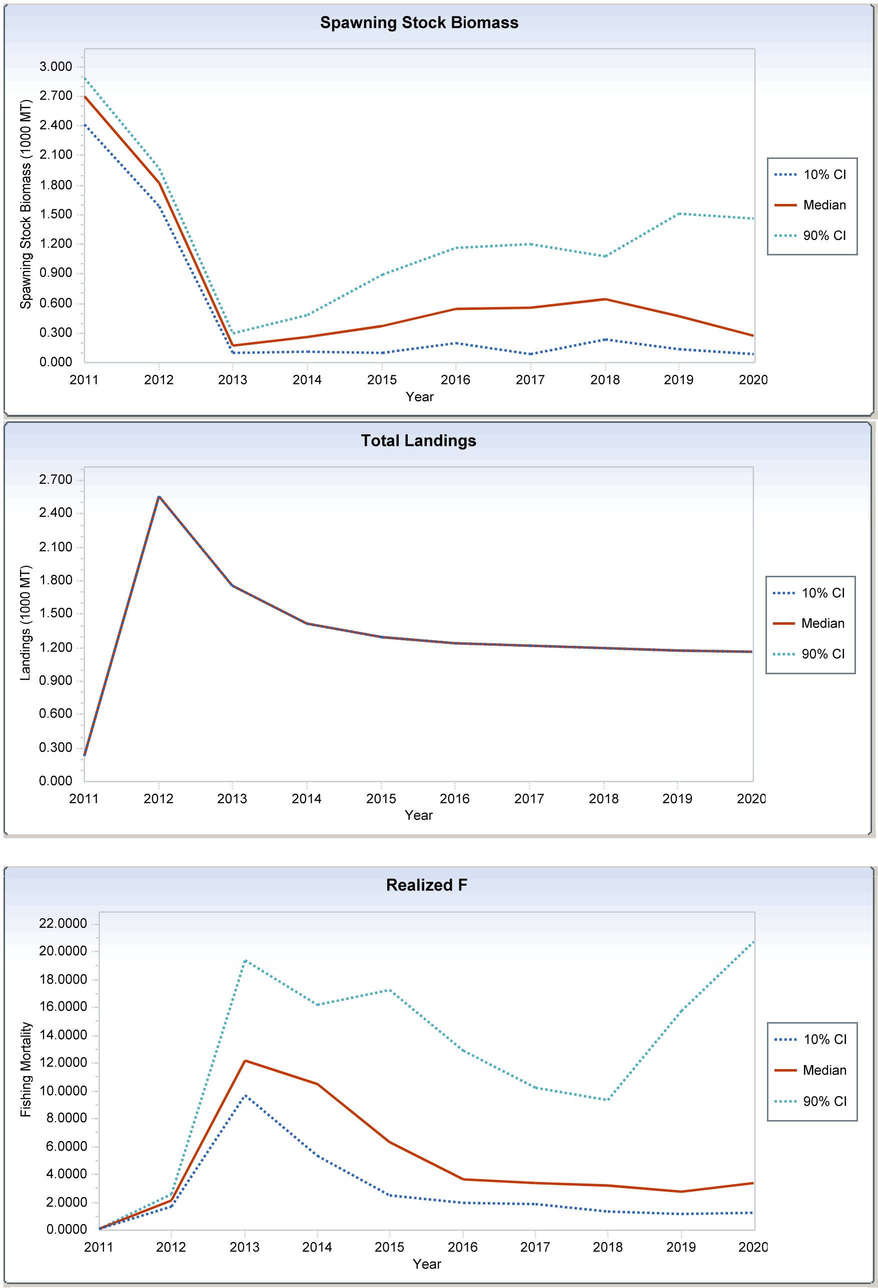


Figure C78. Consequence of the split VPA model reflecting the true when the 75% of Fmsy catch from the ASAP multi model is taken.

C. Assessment of Gulf of Maine (GOM) winter flounder
Appendix C1

[SAW52 Editor's Note: The SARC-52 peer review panel concluded that no ASAP model run provided a suitable basis for management advice. A swept-area biomass method was accepted instead, and it is described in Appendix C1.]

Gulf of Maine winter flounder exploitation rates using 30+ cm biomass from survey area swept estimates

The NEFSC (RV Bigelow series), MDMF, and MENH surveys catch significant numbers of winter flounder per tow. The change in the NEFSC survey vessel and gear to the Bigelow in 2009 has resulted in higher catch efficiency relative to the Albatross series. In addition the sampling intensity has also increased in most of the inshore strata for the Gulf of Maine. The MENH survey covers a large area of this stock that was previous missing prior to 2000. More direct estimates of exploitable biomass through area swept estimates are possible with the recent improvements in fishery independent data sources. Exploitation rates can be inferred from using a range of assumed survey efficiencies (Q) along with consideration of survey stock area coverage and different assumed catches. Possible bounds on the likely recent exploitation rate could be determined. The range of the estimates using different assumptions may help show what the likely exploitation rates are under different catches. A knife edge approximation of exploitable biomass was assumed as legal sized 30+ cm numbers converted to weight from a length-weight equation. Exploitable biomass was estimated as:

Exploitable Biomass = 30+ cm biomass index per tow /1000 x total survey Area/tow footprint x 1/q

and exploitation rate as:

Exploitation rate = catch / 30+ cm biomass

This method could possibly be used to determine the likely exploitation rate and overfishing status for Gulf of Maine winter flounder. However determination on whether the stock is overfished cannot be made since biomass reference points are unknown.

There are several important facts to take into consideration when interpreting the exploitation rate table (Table C1);

1. No single survey covers the entire stock (Appendix C1 Figures C1 to C4)).
2. Winter flounder is a shallow water species with a stock boundary from north of Cape Cod to the Canadian border.

3. Much higher survey catch rates are seen inshore verse offshore strata. However a significant proportion of the stock may be offshore due to the much larger strata area (offshore NEFSC 26, 40, 39).
4. The MENH survey catches significant numbers of fish. However relatively few exploitable 30+ cm fish are seen in the survey (Appendix C1 Figure C5). Updated age data suggests slower growth rates in Maine waters.
5. The most recent three year average biomass was used for the spring and fall MDMF surveys, two years for Bigelow spring survey and only one year for the Bigelow fall survey. The combined biomass estimate was calculated from non-overlapping strata from all three surveys.
6. Most of the catch is taken from statistical area 514 (Cape Cod Bay, Mass Bay, Ipswich Bay, Stellwagen bank). MDMF exploitation estimates conservatively assume that the entire stock is within Massachusetts state waters.
7. A Q equal to 1 conservatively assumes that the survey gear is 100% efficient.
8. The combined estimate using non-overlapping strata from all three surveys covers most of the stock area (Appendix C1 Table C2, Figure C4).

Exploitable 30+ cm biomass and exploitation rates with the associated error distribution were re-estimated from 2004 to 2010 (Appendix C1 Table C3, Figure C6 and C7) using the Survey Area Graphical Analysis (SAGA) program. The 80 percent confidence intervals were plotted to evaluate the inter-annual variation. The Bigelow to Albatross conversion coefficients were not incorporated into the calculations. However the use of the estimated Miller et al (2010) conversion of 2.086 Kg/tow would result in similar biomass estimates between the Albatross and Bigelow series (Appendix C1 Figure C6). Questions with regards to the relative low catchability and inshore sampling coverage in the Albatross series, uncertainty in the conversion coefficients for larger fish and possible effects of changes in stock size over time can be avoided by limiting the analysis to the most recent Bigelow time series (spring 2009 & 2010, fall 2009 & 2010). An analysis limited to strata which overlapped both the NEFSC Bigelow and Massachusetts DMF survey suggests there is relatively little difference in gear efficiency between the surveys (Appendix C1 Figure C8). Adjusting of the area difference in the overlapping strata between the MDMF and NEFSC surveys brings the estimates closer together (Appendix C1 Figure C9). A small difference in the survey gear efficiency helps justify the use of non-overlapping strata among the surveys as a single biomass estimate. A comparison of the survey components used in the combined estimate (MDMF near-shore, NEFSC inshore, NEFSC offshore) between the spring and the fall surveys shows that a higher proportion of the stock close to shore during the spring (Appendix C1 Table C4, Figures C10 and C11). The lower overall 30+ biomass estimates in the spring may be a function of unavailable fish to the surveys that are residing inside the estuaries during the spawning season. However survey information in the fall is also limited since no sampling occurred in Cape Cod bay in the NEFSC Fall 2010 survey. Note the combined fall 2010 estimate is based on a different strata set among the surveys (Appendix C1 Figure C12). The MDMF strata in Cape Cod Bay were used to account for the missing strata in the NEFSC survey. Sensitivity of the biomass estimates to the inclusion of the large deep offshore strata (27, 38) can be seen in Appendix C1 Figure C13. These deep offshore strata (27, 38) were not included in the final estimates due to the lack of fish seen in the deep central Gulf of Maine (Appendix C1 Figure C14).

At the SMAST Fishermen's input meeting fishermen suggested that herding between the doors and ground cable is important for the catchability of winter flounder. This may be more important in the commercial fishery targeted flatfish tows were tow speeds tend to be about a knot slower than a survey tow. Area swept estimates using the doors for the footprint calculation was done as a sensitivity analysis (Appendix C1 Table C5). Using the new TOGA criteria instead of SHG was also done as a sensitivity comparison. The wing based TOGA biomass estimates were slightly higher than estimates based on SHG (Appendix C1 Table C6).

A proxy value of the overfishing threshold (F40%) was derived from a length-based yield per recruit (NFT 2011) analysis that assumes all fish above 30 cm are fully recruited to the fishery and that natural mortality is 0.3 (Appendix C1 Figure C15). Von Bertalanffy parameters were estimated from the spring and fall NEFSC survey age data (n = 2,035) from 2006 to 2010. Maturity at length information is estimated from the spring MDMF survey (L_{50}=29cm). The reference points were converted to exploitation rates to be consistent with the swept area biomass approach. An $F_{40\%}$ exploitation rate was estimated at 0.23 and $75\%F_{40\%}$ exploitation was 0.17 with M=0.3. Appendix C1 Table C7 and Figure C16 show estimated exploitation rates (catch over survey biomass) relative to the estimated exploitation based reference points over a range of catches using the combined surveys (spring and fall 2009 20010) assuming different efficiencies (0.2 to 1.0).

Uncertainty Estimates

Methods

The sampling distributions of biomass and fishing mortality are approximated by integrating over the factors which constitute the primary sources of uncertainty. These factors include the sampling variability in the Northeast Fisheries Science Center (NEFSC), Massachusetts Division of Marine Fisheries (MADMF), and Maine-New Hampshire (MENH) spring and fall bottom surveys for 2009 and 2010. The second major source of variability for the survey estimates is the variation in the size of the area swept by an average tow. The sample means and variances for each of these factors were used to parameterize their respective normal distributions. Sampling theory and boot-strapping analyses for other species suggests that the survey means should be asymptotically normal. We exploit this feature to simplify the estimation of the sampling distribution of biomass and exploitation rate.

The estimator of total stock size can be written as

$$B_{Tot} = A_{NEFSC}\frac{I_{NEFSC}}{e\,a_{NEFSC}} + A_{MADMF}\frac{I_{MADMF}}{e\,a_{MADMF}} + A_{MENH}\frac{I_{MENH}}{e\,a_{MENH}} \quad \text{(Eq. 1)}$$

Where **A** represents the total stratum area, **I** represents the mean index of abundance (kg/tow) for winter flounder greater than 30 cm, and **a** represents the average area swept per tow, and **e** represents the trawl efficiency (probability of capture given encounter). Each of the measures of survey abundance and swept area are measured with uncertainty. In this exercise it is assumed that the total stratum area A is constant and measured without error. The gear efficiency **e** is unknown but cannot be greater than one unless significant herding occurs. If herding does occur the maximum efficiency is approximately equal to the ratio of the trawl door width to the wing width. For the purposes of this exercise, gear efficiency was examined over a range of values between 0.6 and 1.0. The sampling distribution B_{tot} can be estimated by integrating over all possible sources of variation. In this exercise there are six normally distributed random variables to consider I_{NEFSC}, I_{MADMF}, I_{MENH}, a_{NEFSC}, a_{MADMF}, and a_{MENH}. The means and variances of these variables are summarized in Appendix C1 Table C8. The variance of the footprints for the MADMF and MENH survey were not measured. It was assumed that the CV of these estimates was equal to the estimates for the NEFSC survey. All NEFSC survey estimates were conducted on the FSV Bigelow.

The sampling distribution of each of the Fs described above was evaluated by integrating over each of the normal distributions for average weight I, survey footprint ***a***. The density **I** and footprint a parameters were evaluated over 40 equal probability intervals. The full evaluation of the six sources of variability required 40^6 = 4,096,000,000 evaluations. The proposed method is sometimes known as a Latin hypercube approach because it samples each of the distributions over equal probability intervals. In contrast, a parametric bootstrap sampling randomly from each of the component distributions may not adequately characterize the underlying variability. This of course could be tested and compared with the Latin hypercube approach.

Let Φ = Normal cumulative distribution function. The inverse of Φ, denoted as Φ^{-1} ,allows the evaluation of a set of values over a specified range, say α_{min} and α_{max} , over equal probability intervals. The value of the random variable X associated with the α level is defined as:

$$I'_{\alpha} = \Phi^{-1}(\alpha \mid \bar{I}, S_I^2) \text{ (Eq. 2)}$$

The step size between successive values of α was set as δ = 1/40 (0.975-0.025), where α_{min} = 0.025 and α_{max} = 0.975. An equivalent approach was used for evaluation of the footprint parameter **a** where $a \sim N(\mu_a, \sigma_a^2)$.

This property can be illustrated for the biomass estimates by substituting Equation 2 into Eq. 1 and integrating over all possible step sizes. Let i, j, k, l, m, n represent the indices for survey and footprint components, and let a prime denote the value of each component that is derived by evaluating Eq. 2. corresponding the α probability level.

The expected value of $\boldsymbol{B_{tot}}$ is obtained by summing over the sampling distributions of ***X*** and ***a*** as follows:

$$E[B_{Tot}] = \sum_{i=1}^{40}\sum_{j=1}^{40}\sum_{k=1}^{40}\sum_{l=1}^{40}\sum_{m=1}^{40}\sum_{n=1}^{40}\left[A_{NEFSC}\frac{I'_i}{e\,a'_j} + A_{MADMF}\frac{I'_k}{e\,a'_l} + A_{MENH}\frac{I'_m}{e\,a'_n}\right]\delta^6$$

(Eq .3)

The sampling distribution of ***Btot*** can be constructed by noting that the each element within the brackets of the rhs of Equation 3 has a probability weight of δ =(1/40).

The sampling distribution of F is simply the assumed value of the quota divided by the estimate of the biomass in Equation 3. This approximation of the multidimensional integration provides reasonable assurance that the sampling distribution of the F and B will be appropriately estimated.

Results of Uncertainty Analyses

Summary statistics for the biomass estimates are provided in Appendix C1 Table C9 and plotted in Appendix C1 Figure *C*. Under the null hypothesis that the distribution is normally distributed, the sample statistics for skewness and kurtosis estimates have expected values of zero. Values of skewness greater than zero indicate positive skewing (i.e, a longer tail on the right or in a positive direction from the mean). Values of kurtosis greater than zero provide evidence that the sampling distribution is more peaked than a normal distribution with a comparable mean and variance.

Exploitation rate distributions relative to exploitation rate biological reference points are shown in Appendix C1 Figures C18 through C21. The probability of exceeding candidate biological reference points are provided graphically in Appendix C1 Figures C22 and C23.

Survey Area Swept 30+ cm Exploitation Rates Conclusions

The use of an efficiency value of 0.6 was supported by comparison of VPA estimates of efficiency for the Georges Bank winter flounder while making the assumption that the same fraction of each stock is available to the respective surveys. The NEFSC fall survey (expressed in Albatross equivalents) had an efficiency estimate of 0.3. Calibration experiments between the FSV Bigelow and the R/V Albatross revealed a biomass conversion coefficient of ~2. Thus an efficiency estimate for the Bigelow survey estimate in 2010 of 0.6 was supported. An analysis of catch rates in overlapping areas by the NEFSC and MADMF surveys demonstrated similar catchabilities for winter flounder by the two surveys.

The SARC concluded that the best estimate of 30+ cm biomass and recent (2010) exploitation is based on use of the TOGA tow criteria for the fall 2010 surveys assuming an efficiency of 0.6 (Appendix C1 Tables C6 and C10 and Figure C14). The overfishing status is based on the ratio of 2010 catch (195 mt) to survey based swept area estimate of biomass for winter flounder exceeding 30 cm in length (6,341 mt). Exploitation rate in 2010 was estimated at 0.03 (80% CI 0.02 - 0.05) and therefore overfishing is not occurring (F2010/F40 ratio = 0.13, Appendix C1 Figure C24). This conclusion is robust to the range of uncertainty in the biomass estimate (Appendix C1 Figures C18 through C21). The biomass estimate for 2010 is 16% lower than that for 2009 using the same survey methods but this difference is not statistically significant (Appendix C1 Figure C17).

Appendix C1 Table C1. A range of estimated 30+ cm biomass and exploitation rates for different surveys using a range of assumed qs (1, 0.8, 0.6, 0.4) and assumed catch (mt) or ABCs (238, 344, 500, 800). A combined estimate using non-overlapping strata is also shown. Exploitation rates exceeding 0.2 are highlighted.

Q = 0.4	Catch	Bigelow Spring	Bigelow Fall	MDMF Spring	MDMF Fall	Combined Spring	Combined Fall
30+ Biomass		3,520	10,271	2,895	3,713	7,074	11,390
ABC	238	0.07	0.02	0.08	0.06	0.03	0.02
3yr avg	344	0.10	0.03	0.12	0.09	0.05	0.03
	500	0.14	0.05	0.17	0.13	0.07	0.04
	800	0.23	0.08	0.28	0.22	0.11	0.07
Q = 0.6							
30+ Biomass		2,347	6,847	1,930	2,475	4,716	7,593
ABC	238	0.10	0.03	0.12	0.10	0.05	0.03
3yr avg	344	0.15	0.05	0.18	0.14	0.07	0.05
	500	0.21	0.07	0.26	0.20	0.11	0.07
	800	0.34	0.12	0.41	0.32	0.17	0.11
Q = 0.8							
30+ Biomass		1,760	5,135	1,448	1,856	3,537	5,695
ABC	238	0.14	0.05	0.16	0.13	0.07	0.04
3yr avg	344	0.20	0.07	0.24	0.19	0.10	0.06
	500	0.28	0.10	0.35	0.27	0.14	0.09
	800	0.45	0.16	0.55	0.43	0.23	0.14
Q = 1							
30+ Biomass		1,408	4,108	1,158	1,485	2,829	4,556
ABC	238	0.17	0.06	0.21	0.16	0.08	0.05
3yr avg	344	0.24	0.08	0.30	0.23	0.12	0.08
	500	0.36	0.12	0.43	0.34	0.18	0.11
	800	0.57	0.19	0.69	0.54	0.28	0.18

Appendix C1 Table C2 - Survey total area coverage, average tow footprint, kg/tow and expansion factors for non-overlapping strata used in the combined estimate.

	Combined Survey Estimate		
	NEFSC	ME/NH	MDMF
survey area (nm2)	2,990	3,475	309
Avg tow (area swept)	0.007	0.00462	0.003846
Total area/tow footprint	427,143	752,154	80,343
Tow duration	20 min	20 min	20 min
Numbers per tow	34-65	35	80
Proportion of 30+ biomass	0.59	0.09	0.33

Appendix C1 Table C3 - Survey total area coverage, average tow footprint, kg/tow expansion factors and tow during for the different surveys and survey components. NEFSC offshore (39,40,26) = 2322 nm^2, NEFSC inshore overlap (59,60,61,64,65,66) = 668 nm^2, MDMF overlap (27,28,29,30,34,35,36) = 484 nm^2,MDMF near shore (25,26,31,32,33) = 309 nm^2

A. Wing spread

	NEFSC							MDMF				MEHN
	Albatross			Bigelow				Gloria Michele				
	inshore overlap	offshore	combined	inshore overlap	offshore	Fall 2010	combined	state waters	near shore	Fall 2010	overlap	state waters
survey area (nm2)	668	2,322	2,990	668	2,322	2,638	2,990	793	309	633	484	3,475
Avg tow (area swept)	0.0112	0.0112	0.0112	0.007	0.007	0.007	0.007	0.003846	0.00385	0.003846	0.00385	0.00462
Total area/tow footprint	59,643	207,321	266,964	95,429	331,714	376,857	427,143	206,188	80,343	164,587	125,845	752,165
Tow duration	30 min	30 min	30 min	20 min	20 min	20 min	20 min	20 min	20 min	20 min	20 min	20 min

B. Door spread

	NEFSC				MDMF				MEHN
	Bigelow				Gloria Michele				
	inshore overlap	offshore	Fall 2010	combined	state waters	near shore	Fall 2010	overlap	state waters
survey area (nm2)	668	2,322	2,638	2,990	793	309	633	484	3,475
Avg tow (area swept)	0.0177	0.0177	0.0177	0.0177	0.0125	0.0125	0.0125	0.0125	0.0123
Total area/tow footprint	37,845	131,550	149,453	169,395	63,502	24,744	50,690	38,758	282,469
Tow duration	20 min	20 min	20 min	20 min	20 min	20 min	20 min	20 min	20 min

Appendix C1 Table C4 - A range of estimated 30+ cm biomass based on wing spread and exploitation rates for the combined survey estimate in spring 2009, spring 2010, fall 2009 and fall 2010 using a a range of qs assumptions (0.6, 0.8, & 1.0) and a range of assumed catch (mt) (238, 344, 400, 500, 800) based on an shg criteria of 136. The proportion of the biomass in each survey area is also shown. * Fall 2010 estimate is based on a different strata set since the NEFSC Fall survey did not cover Cape Cod bay strata.

Q=1				Total	Exploitation from assumed catch				
	NEFSC	MDMF	ME/NH	30+ biomass	238	344	400	500	800
Spring 2009	0.54	0.26	0.20	3,072	0.08	0.11	0.13	0.16	0.26
Spring 2010	0.45	0.33	0.21	2,587	0.09	0.13	0.15	0.19	0.31
Spring avg	0.49	0.30	0.21	2,829	0.08	0.12	0.14	0.18	0.28
Fall 2009	0.90	0.06	0.03	4,556	0.05	0.08	0.09	0.11	0.18
Fall 2010*	0.65	0.30	0.06	3,293	0.07	0.10	0.12	0.15	0.24

Q=0.8				Total	Exploitation from assumed catch				
	NEFSC	MDMF	ME/NH	30+ biomass	238	344	400	500	800
Spring 2009	0.54	0.26	0.20	3,840	0.06	0.09	0.10	0.13	0.21
Spring 2010	0.45	0.33	0.21	3,233	0.07	0.11	0.12	0.15	0.25
Spring avg	0.49	0.30	0.21	3,537	0.07	0.10	0.11	0.14	0.23
Fall 2009	0.90	0.06	0.03	5,695	0.04	0.06	0.07	0.09	0.14
Fall 2010*	0.65	0.30	0.06	4,116	0.06	0.08	0.10	0.12	0.19

Q=0.6				Total	Exploitation from assumed catch				
	NEFSC	MDMF	ME/NH	30+ biomass	238	344	400	500	800
Spring 2009	0.54	0.26	0.20	5,121	0.05	0.07	0.08	0.10	0.16
Spring 2010	0.45	0.33	0.21	4,311	0.06	0.08	0.09	0.12	0.19
Spring avg	0.49	0.30	0.21	4,716	0.05	0.07	0.08	0.11	0.17
Fall 2009	0.90	0.06	0.03	7,593	0.03	0.05	0.05	0.07	0.11
Fall 2010*	0.65	0.30	0.06	5,489	0.04	0.06	0.07	0.09	0.15

Appendix C1 Table C5 - A range of estimated 30+ cm biomass based on door spread and exploitation rates for the combined survey estimate in spring 2009, spring 2010, fall 2009 and fall 2010 using a a range of qs assumptions (0.6, 0.8, & 1.0) and a range of assumed catch (mt) (238, 344, 400, 500, 800) based on an shg criteria of 136. The proportion of the biomass in each survey area is also shown. * Fall 2010 estimate is based on a different strata set since the NEFSC Fall survey did not cover Cape Cod bay strata.

Q=1				Total	Exploitation from assumed catch				
	NEFSC	MDMF	ME/NH	30+ biomass	238	344	400	500	800
Spring 2009	0.43	0.16	0.40	1,516	0.16	0.23	0.26	0.33	0.53
Spring 2010	0.36	0.21	0.43	1,283	0.19	0.27	0.31	0.39	0.62
Spring avg	0.40	0.19	0.42	1,399	0.17	0.25	0.29	0.36	0.57
Fall 2009	0.87	0.05	0.08	1,877	0.13	0.18	0.21	0.27	0.43
Fall 2010*	0.64	0.23	0.14	1,328	0.18	0.26	0.30	0.38	0.60

A=0.8				Total	Exploitation from assumed catch				
	NEFSC	MDMF	ME/NH	30+ biomass	238	344	400	500	800
Spring 2009	0.43	0.16	0.40	1,895	0.13	0.18	0.21	0.26	0.42
Spring 2010	0.36	0.21	0.43	1,604	0.15	0.21	0.25	0.31	0.50
Spring avg	0.40	0.19	0.42	1,749	0.14	0.20	0.23	0.29	0.46
Fall 2009	0.87	0.05	0.08	2,347	0.10	0.15	0.17	0.21	0.34
Fall 2010*	0.64	0.23	0.14	1,660	0.14	0.21	0.24	0.30	0.48

				Total	Exploitation from assumed catch				
	NEFSC	MDMF	ME/NH	30+ biomass	238	344	400	500	800
Spring 2009	0.43	0.16	0.40	2,526	0.09	0.14	0.16	0.20	0.32
Spring 2010	0.36	0.21	0.43	2,139	0.11	0.16	0.19	0.23	0.37
Spring avg	0.40	0.19	0.42	2,332	0.10	0.15	0.17	0.21	0.34
Fall 2009	0.87	0.05	0.08	3,129	0.08	0.11	0.13	0.16	0.26
Fall 2010*	0.64	0.23	0.14	2,214	0.11	0.16	0.18	0.23	0.36

Appendix C1 Table C6 - A range of estimated 30+ cm biomass based on wing spread and exploitation rates for the combined survey estimate in spring 2009, spring 2010, fall 2009 and fall 2010 using a a range of qs assumptions (0.6, 0.8, & 1.0) and a range of assumed catch (mt) (238, 344, 400, 500, 800) based on an TOGA criteria of 132x. The proportion of the biomass in each survey area is also shown. * Fall 2010 estimate is based on a different strata set since the NEFSC Fall survey did not cover Cape Cod bay strata.

Q=1				Total	Exploitation from assumed catch				
	NEFSC	MDMF	ME/NH	30+ biomass	238	344	400	500	800
Spring 2009	0.56	0.25	0.19	3,212	0.07	0.11	0.125	0.16	0.25
Spring 2010	0.45	0.33	0.21	2,594	0.09	0.13	0.154	0.19	0.31
Spring avg	0.50	0.29	0.20	2,903	0.08	0.12	0.138	0.17	0.28
Fall 2009	0.90	0.06	0.03	4,567	0.05	0.08	0.088	0.11	0.18
Fall 2010*	0.69	0.26	0.05	3,804	0.06	0.09	0.105	0.13	0.21

Q=0.8				Total	Exploitation from assumed catch				
	NEFSC	MDMF	ME/NH	30+ biomass	238	344	400	500	800
Spring 2009	0.56	0.25	0.19	4,015	0.06	0.09	0.100	0.12	0.20
Spring 2010	0.45	0.33	0.21	3,243	0.07	0.11	0.123	0.15	0.25
Spring avg	0.50	0.29	0.20	3,629	0.07	0.09	0.110	0.14	0.22
Fall 2009	0.90	0.06	0.03	5,709	0.04	0.06	0.070	0.09	0.14
Fall 2010*	0.69	0.26	0.05	4,756	0.05	0.07	0.084	0.11	0.17

Q=0.6				Total	Exploitation from assumed catch				
	NEFSC	MDMF	ME/NH	30+ biomass	238	344	400	500	800
Spring 2009	0.56	0.25	0.19	5,354	0.04	0.06	0.075	0.09	0.15
Spring 2010	0.45	0.33	0.21	4,324	0.06	0.08	0.093	0.12	0.19
Spring avg	0.50	0.29	0.20	4,839	0.05	0.07	0.083	0.10	0.17
Fall 2009	0.90	0.06	0.03	7,612	0.03	0.05	0.053	0.07	0.11
Fall 2010*	0.69	0.26	0.05	6,341	0.04	0.05	0.063	0.08	0.13

Appendix C1 Table C7 – Exploitation ratios at various levels of catch and assumed trawl efficiency using 30+ cm swept area biomass from combined surveys.

	catch	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
Efficiency = 1	30+biomass																				
Spring 2009	3,212	0.016	0.031	0.047	0.062	0.078	0.093	0.109	0.125	0.140	0.156	0.171	0.187	0.202	0.218	0.233	0.249	0.265	0.280	0.296	0.311
Spring 2010	2,594	0.019	0.039	0.058	0.077	0.096	0.116	0.135	0.154	0.173	0.193	0.212	0.231	0.251	0.270	0.289	0.308	0.328	0.347	0.366	0.385
Spring avg	2,903	0.017	0.034	0.052	0.069	0.086	0.103	0.121	0.138	0.155	0.172	0.189	0.207	0.224	0.241	0.258	0.276	0.293	0.310	0.327	0.344
Fall 2009	4,567	0.011	0.022	0.033	0.044	0.055	0.066	0.077	0.088	0.099	0.109	0.120	0.131	0.142	0.153	0.164	0.175	0.186	0.197	0.208	0.219
Fall 2010	3,804	0.013	0.026	0.039	0.053	0.066	0.079	0.092	0.105	0.118	0.131	0.145	0.158	0.171	0.184	0.197	0.210	0.223	0.237	0.250	0.263
Fall avg	4,186	0.012	0.024	0.036	0.048	0.060	0.072	0.084	0.096	0.108	0.119	0.131	0.143	0.155	0.167	0.179	0.191	0.203	0.215	0.227	0.239
	catch	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
Efficiency = 0.8	30+biomass																				
Spring 2009	4,015	0.012	0.025	0.037	0.050	0.062	0.075	0.087	0.100	0.112	0.125	0.137	0.149	0.162	0.174	0.187	0.199	0.212	0.224	0.237	0.249
Spring 2010	3,243	0.015	0.031	0.046	0.062	0.077	0.093	0.108	0.123	0.139	0.154	0.170	0.185	0.200	0.216	0.231	0.247	0.262	0.278	0.293	0.308
Spring avg	3,629	0.014	0.028	0.041	0.055	0.069	0.083	0.096	0.110	0.124	0.138	0.152	0.165	0.179	0.193	0.207	0.220	0.234	0.248	0.262	0.276
Fall 2009	5,709	0.009	0.018	0.026	0.035	0.044	0.053	0.061	0.070	0.079	0.088	0.096	0.105	0.114	0.123	0.131	0.140	0.149	0.158	0.166	0.175
Fall 2010	4,756	0.011	0.021	0.032	0.042	0.053	0.063	0.074	0.084	0.095	0.105	0.116	0.126	0.137	0.147	0.158	0.168	0.179	0.189	0.200	0.210
Fall avg	5,232	0.010	0.019	0.029	0.038	0.048	0.057	0.067	0.076	0.086	0.096	0.105	0.115	0.124	0.134	0.143	0.153	0.162	0.172	0.182	0.191
	catch	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
Efficiency = 0.6	30+biomass																				
Spring 2009	5,354	0.009	0.019	0.028	0.037	0.047	0.056	0.065	0.075	0.084	0.093	0.103	0.112	0.121	0.131	0.140	0.149	0.159	0.168	0.177	0.187
Spring 2010	4,324	0.012	0.023	0.035	0.046	0.058	0.069	0.081	0.093	0.104	0.116	0.127	0.139	0.150	0.162	0.173	0.185	0.197	0.208	0.220	0.231
Spring avg	4,839	0.010	0.021	0.031	0.041	0.052	0.062	0.072	0.083	0.093	0.103	0.114	0.124	0.134	0.145	0.155	0.165	0.176	0.186	0.196	0.207
Fall 2009	7,612	0.007	0.013	0.020	0.026	0.033	0.039	0.046	0.053	0.059	0.066	0.072	0.079	0.085	0.092	0.099	0.105	0.112	0.118	0.125	0.131
Fall 2010	6,341	0.008	0.016	0.024	0.032	0.039	0.047	0.055	0.063	0.071	0.079	0.087	0.095	0.103	0.110	0.118	0.126	0.134	0.142	0.150	0.158
Fall avg	6,977	0.007	0.014	0.022	0.029	0.036	0.043	0.050	0.057	0.065	0.072	0.079	0.086	0.093	0.100	0.108	0.115	0.122	0.129	0.136	0.143
	catch	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
Efficiency = 0.4	30+biomass																				
Spring 2009	8,030	0.006	0.012	0.019	0.025	0.031	0.037	0.044	0.050	0.056	0.062	0.068	0.075	0.081	0.087	0.093	0.100	0.106	0.112	0.118	0.125
Spring 2010	6,486	0.008	0.015	0.023	0.031	0.039	0.046	0.054	0.062	0.069	0.077	0.085	0.093	0.100	0.108	0.116	0.123	0.131	0.139	0.146	0.154
Spring avg	7,258	0.007	0.014	0.021	0.028	0.034	0.041	0.048	0.055	0.062	0.069	0.076	0.083	0.090	0.096	0.103	0.110	0.117	0.124	0.131	0.138
Fall 2009	11,419	0.004	0.009	0.013	0.018	0.022	0.026	0.031	0.035	0.039	0.044	0.048	0.053	0.057	0.061	0.066	0.070	0.074	0.079	0.083	0.088
Fall 2010	9,511	0.005	0.011	0.016	0.021	0.026	0.032	0.037	0.042	0.047	0.053	0.058	0.063	0.068	0.074	0.079	0.084	0.089	0.095	0.100	0.105
Fall avg	10,465	0.005	0.010	0.014	0.019	0.024	0.029	0.033	0.038	0.043	0.048	0.053	0.057	0.062	0.067	0.072	0.076	0.081	0.086	0.091	0.096
	catch	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
Efficiency = 0.2	30+biomass																				
Spring 2009	16,061	0.003	0.006	0.009	0.012	0.016	0.019	0.022	0.025	0.028	0.031	0.034	0.037	0.040	0.044	0.047	0.050	0.053	0.056	0.059	0.062
Spring 2010	12,972	0.004	0.008	0.012	0.015	0.019	0.023	0.027	0.031	0.035	0.039	0.042	0.046	0.050	0.054	0.058	0.062	0.066	0.069	0.073	0.077
Spring avg	14,517	0.003	0.007	0.010	0.014	0.017	0.021	0.024	0.028	0.031	0.034	0.038	0.041	0.045	0.048	0.052	0.055	0.059	0.062	0.065	0.069
Fall 2009	22,837	0.002	0.004	0.007	0.009	0.011	0.013	0.015	0.018	0.020	0.022	0.024	0.026	0.028	0.031	0.033	0.035	0.037	0.039	0.042	0.044
Fall 2010	19,022	0.003	0.005	0.008	0.011	0.013	0.016	0.018	0.021	0.024	0.026	0.029	0.032	0.034	0.037	0.039	0.042	0.045	0.047	0.050	0.053
Fall avg	20,930	0.002	0.005	0.007	0.010	0.012	0.014	0.017	0.019	0.022	0.024	0.026	0.029	0.031	0.033	0.036	0.038	0.041	0.043	0.045	0.048

Appendix C1 Table C8 - Summary of model input data for estimation of swept area biomass estimates for GOM winter flounder.

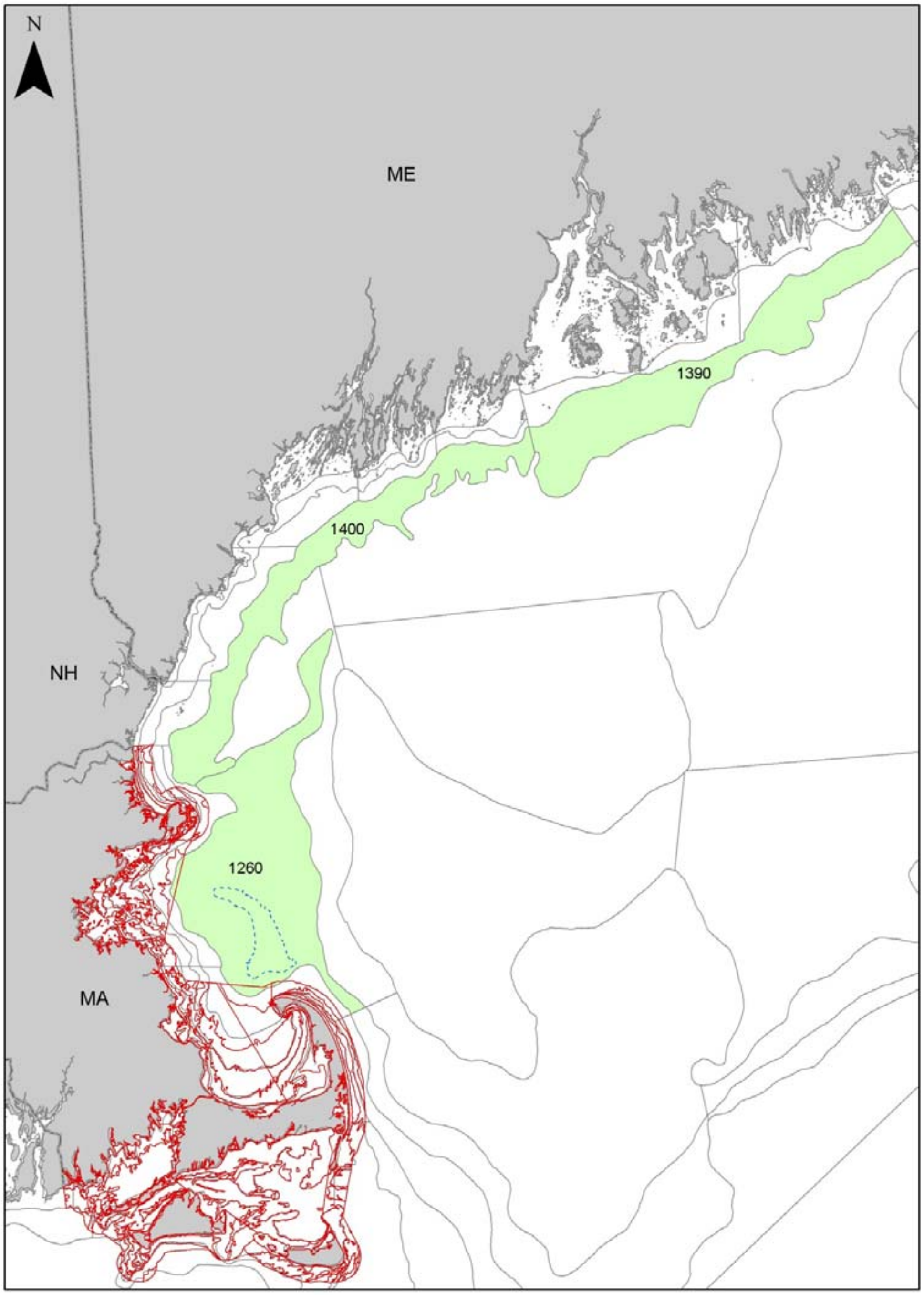
Survey	Season	Year	Total Survey Area in nm^2	Area per tow in nm^2 (SE)	Survey in kg/tow (SE)
NEFSC	Spring	2009	2990	0.006974755 (0.000835526)	4.18909 (1.68859)
MADMF			309	0.003846 (0.0004607)	10.0972 (1.63578)
ME-NH			3475	0.00462 (0.000553443)	0.81315 (0.13173)
NEFSC	Fall	2009	2990	0.006974755 (0.000835526)	9.6447 (4.10327)
MADMF			309	0.003846 (0.0004607)	3.59066 (0.627)
ME-NH			3475	0.00462 (0.000553443)	0.21176 (0.03698)
NEFSC	Spring	2010	2990	0.006974755 (0.000835526)	2.74878 (0.60754)
MADMF			309	0.003846 (0.0004607)	10.7822 (2.8331)
ME-NH			3475	0.00462 (0.000553443)	0.73656 (0.19354)
NEFSC	Fall	2010	2638	0.006974755 (0.000835526)	7.00897 (2.97247)
MADMF			633	0.003846 (0.0004607)	5.96533 (0.855255)
ME-NH			3475	0.00462 (0.000553443)	0.240953 (0.03455)

Appendix C1 Table C9 - Summary of estimated sampling distribution of biomass estimates for Gulf of Maine winter flounder for varying seasons, years and assumed survey efficiency estimates.

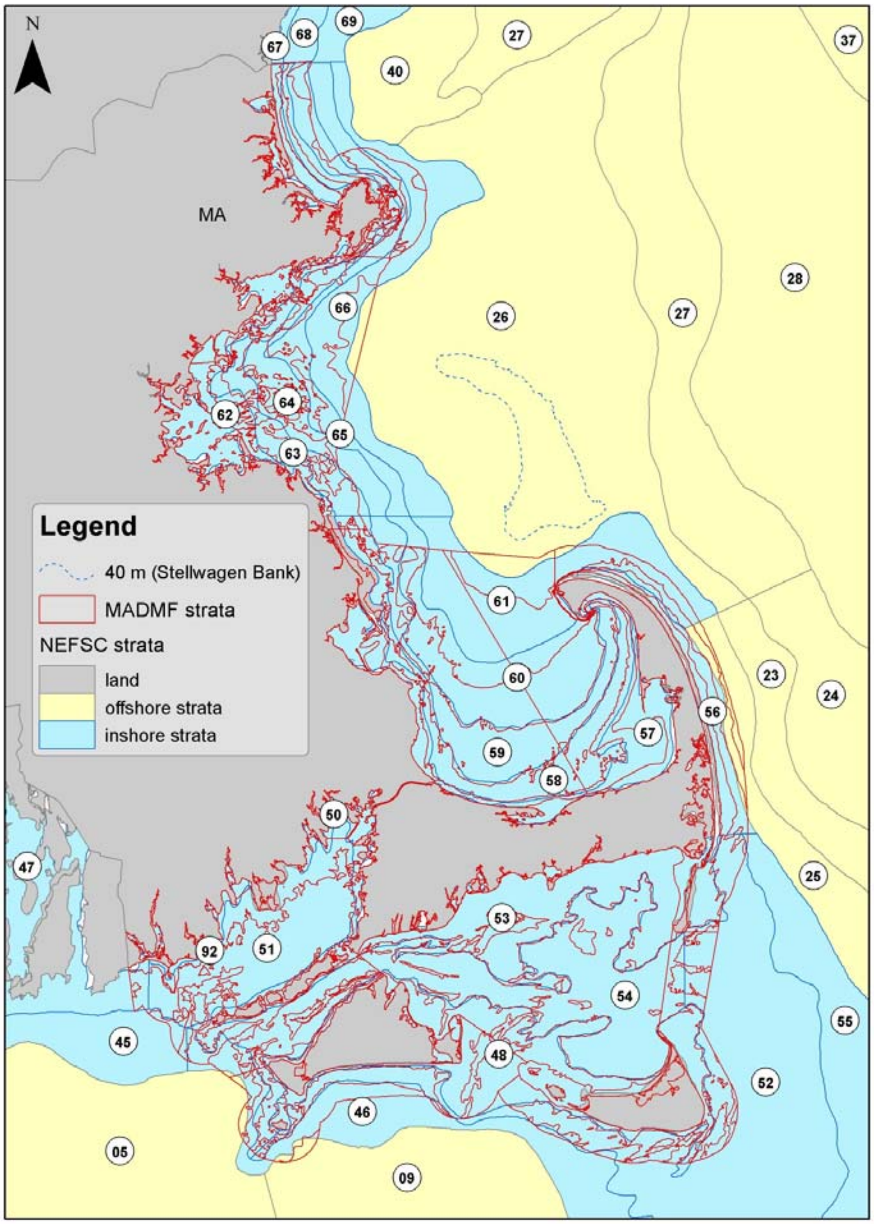
	Fall2009			*Spring2009*			*Spring2010*			*Fall2010*		
	0.6	***0.8***	***1***	***0.6***	***0.8***	***1***	***0.6***	***0.8***	***1***	***0.6***	***0.8***	***1***
Min	2,260	1,680	1,330	2,890	2,150	1,700	2,590	1,920	1,520	2,610	1,940	1,540
Max	15,690	12,400	9,930	8,240	6,230	5,010	6,540	4,940	3,970	11,870	8,990	7,240
Range	13,430	10,720	8,600	5,350	4,080	3,310	3,950	3,020	2,450	9,260	7,050	5,700
Mean	7,761	5,826	4,659	5,203	3,899	3,116	4,375	3,278	2,620	6,468	4,849	3,877
SD	2,643	1,995	1,599	913	686	550	612	460	368	1,721	1,295	1,037
CV	0.341	0.342	0.343	0.176	0.176	0.176	0.14	0.14	0.141	0.266	0.267	0.268
Skewness	0.231	0.248	0.249	0.242	0.246	0.249	0.191	0.195	0.195	0.237	0.242	0.245
Kurtosis	-0.471	-0.434	-0.432	-0.332	-0.32	-0.313	-0.178	-0.165	-0.157	-0.432	-0.422	-0.414
Percentiles												
1%	2,700	2,020	1,610	3,380	2,530	2,020	3,070	2,300	1,840	3,150	2,350	1,880
5%	3,560	2,670	2,130	3,770	2,820	2,250	3,400	2,550	2,030	3,750	2,800	2,240
10%	4,300	3,220	2,570	4,030	3,020	2,410	3,600	2,690	2,150	4,230	3,160	2,530
20%	5,360	4,020	3,210	4,390	3,290	2,630	3,840	2,880	2,300	4,910	3,680	2,940
25%	5,800	4,350	3,470	4,530	3,400	2,710	3,940	2,950	2,360	5,190	3,890	3,110
30%	6,200	4,650	3,710	4,670	3,500	2,800	4,030	3,020	2,410	5,450	4,090	3,270
40%	6,940	5,200	4,160	4,920	3,690	2,950	4,200	3,140	2,510	5,930	4,450	3,550
50%	7,650	5,740	4,590	5,160	3,870	3,090	4,350	3,260	2,610	6,390	4,790	3,830
60%	8,370	6,280	5,020	5,410	4,050	3,240	4,510	3,380	2,700	6,860	5,140	4,110
70%	9,150	6,870	5,490	5,670	4,250	3,400	4,690	3,510	2,810	7,370	5,530	4,420
75%	9,590	7,200	5,760	5,820	4,360	3,490	4,790	3,590	2,870	7,650	5,740	4,590
80%	10,080	7,570	6,050	5,990	4,490	3,590	4,890	3,670	2,930	7,970	5,980	4,780
90%	11,350	8,530	6,820	6,430	4,820	3,850	5,180	3,890	3,110	8,800	6,600	5,280
95%	12,350	9,290	7,430	6,780	5,090	4,070	5,420	4,070	3,250	9,450	7,090	5,680
99%	14,010	10,570	8,470	7,410	5,560	4,450	5,860	4,400	3,520	10,560	7,930	6,350

Appendix C1**Table C10. Summary of sampling distribution for exploitation rates for the Fall 2010 with an assumed efficiency of 0.6 and the 2010 catch of 195 mt for Gulf of Maine winter flounder.**

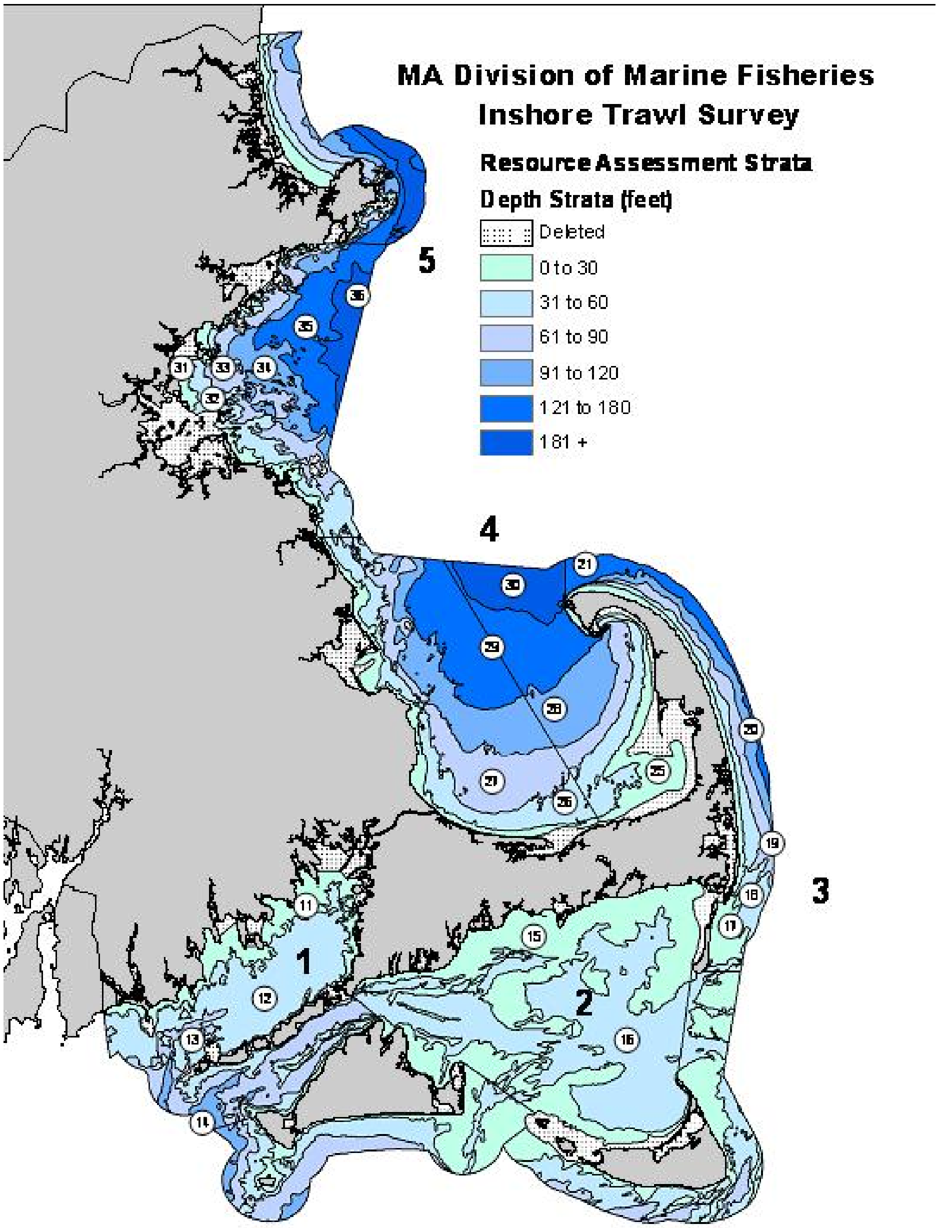
Minimum	**0.015**
Maximum	**0.076**
Range	**0.061**
Mean	**0.032**
Standard Dev	**0.010**
C.V.	**0.302**
Skewness(G1)	**1.057**
Kurtosis(G2)	**1.021**
Method = EMPCDF	
1 %	**0.018**
5 %	**0.020**
10 %	**0.022**
20 %	**0.024**
25 %	**0.025**
30 %	**0.026**
40 %	**0.028**
50 %	**0.030**
60 %	**0.032**
70 %	**0.035**
75 %	**0.037**
80 %	**0.039**
90 %	**0.046**
95 %	**0.051**
99 %	**0.061**



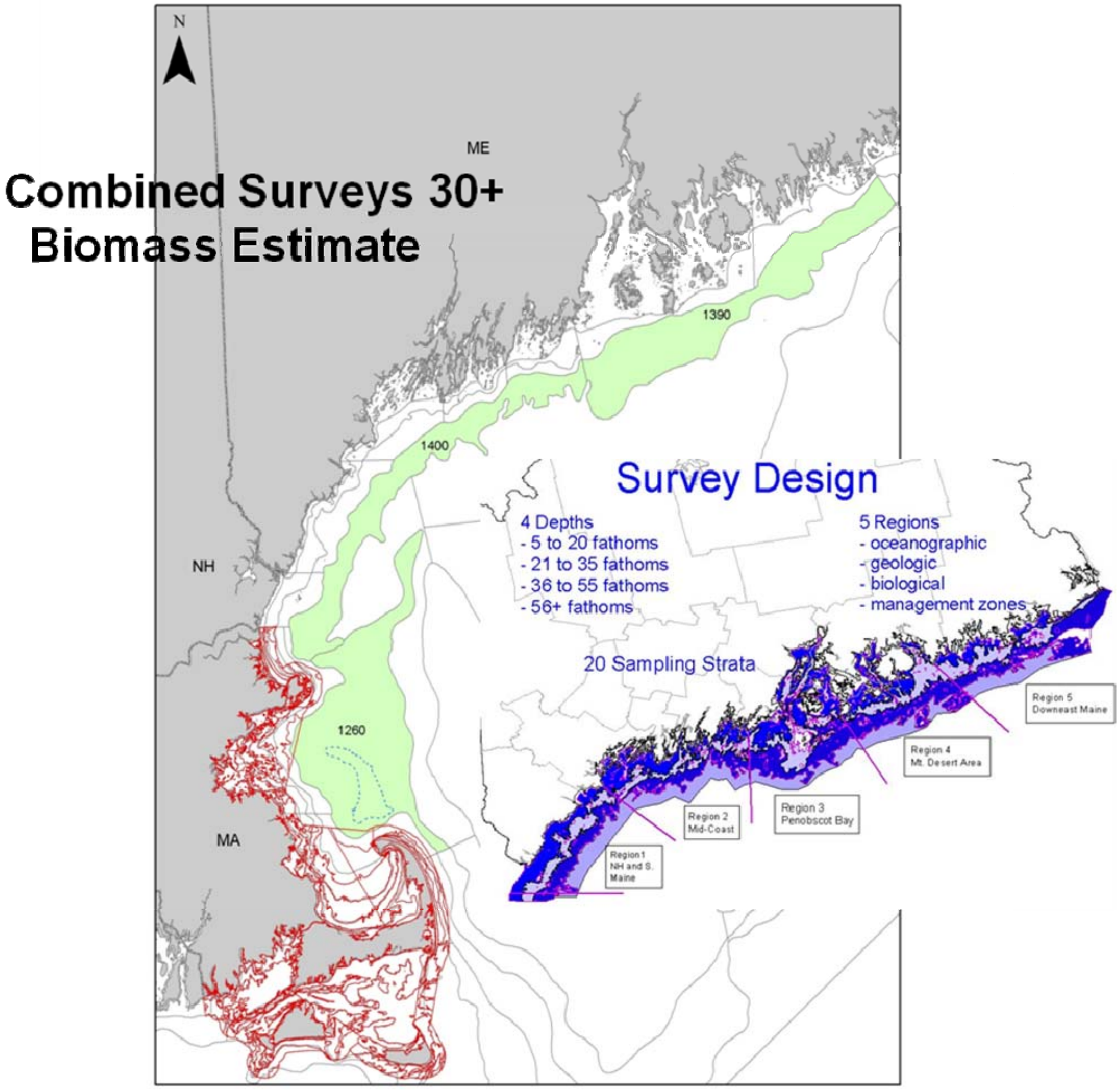
Appendix C1 Figure C1 - Gulf of Maine winter flounder inshore and offshore survey coverage map. Green shaded areas are the NEFSC offshore strata used for the 30+ biomass estimate.



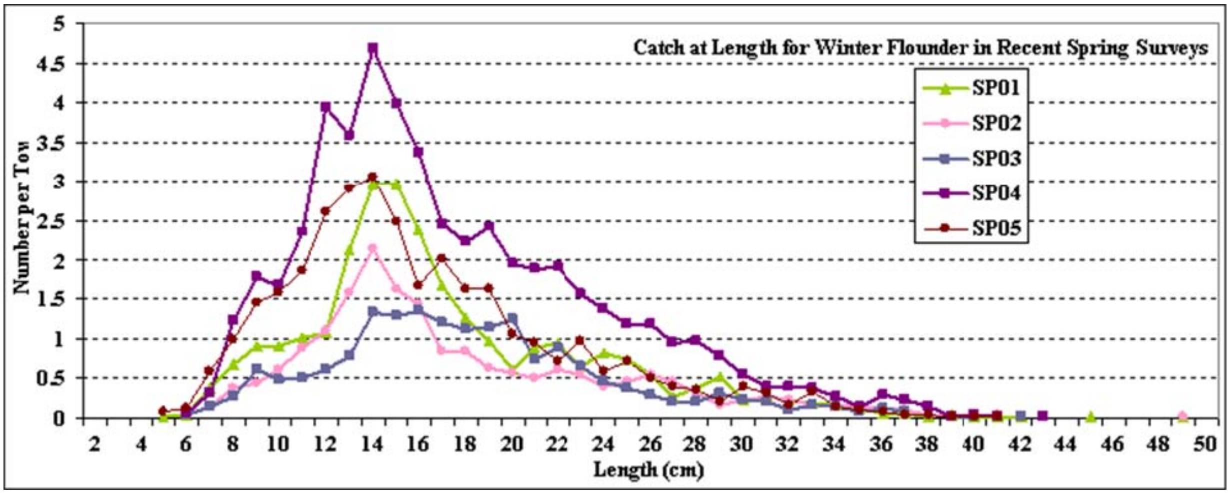
Appendix C1 Figure C2 - Gulf of Maine winter flounder inshore survey overlap between the NEFSC and MDMF surveys.



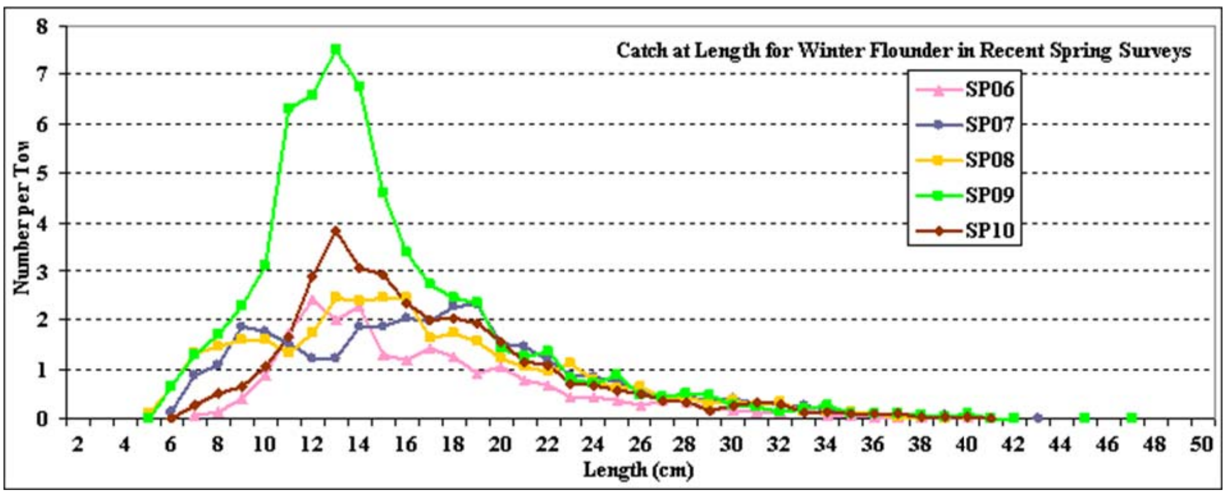
Appendix C1 Figure C3 - MDMF survey strata. The gulf of Maine winter flounder stock uses strata north of Cape Cod.



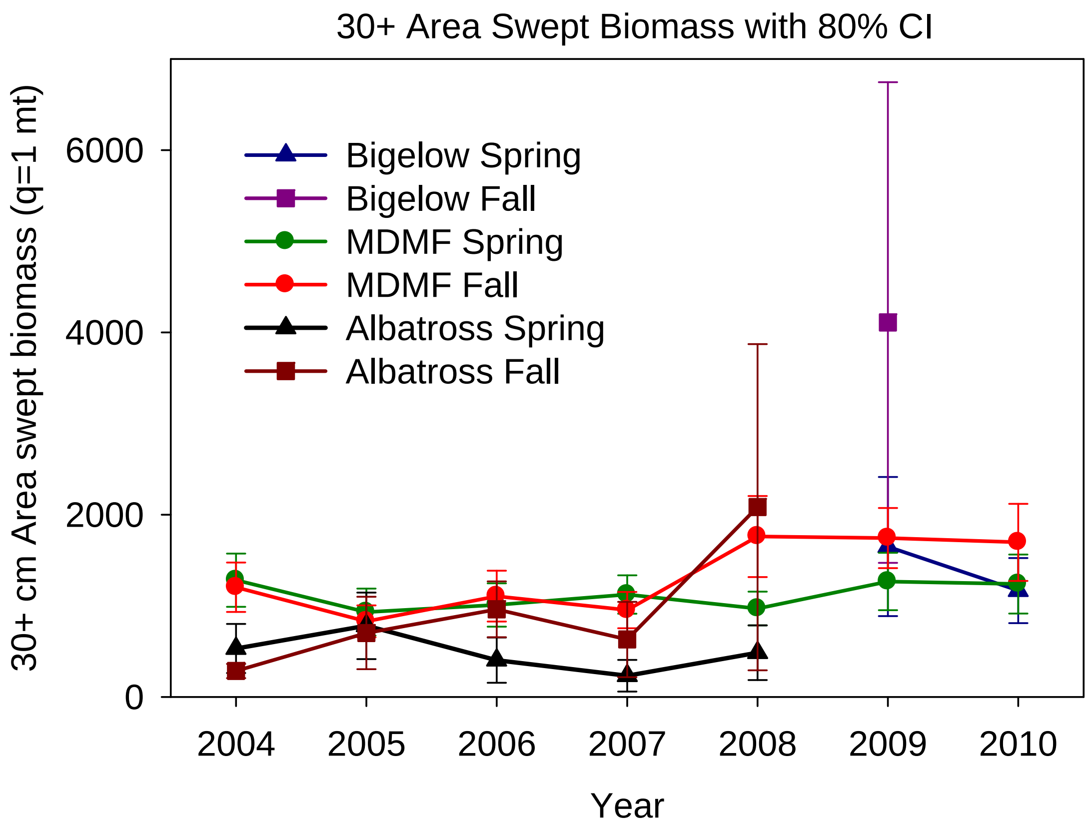
Appendix C1 Figure C4 - NEFSC, MDMF, and MENH survey areas used in the combined survey 30+ cm biomass estimate.



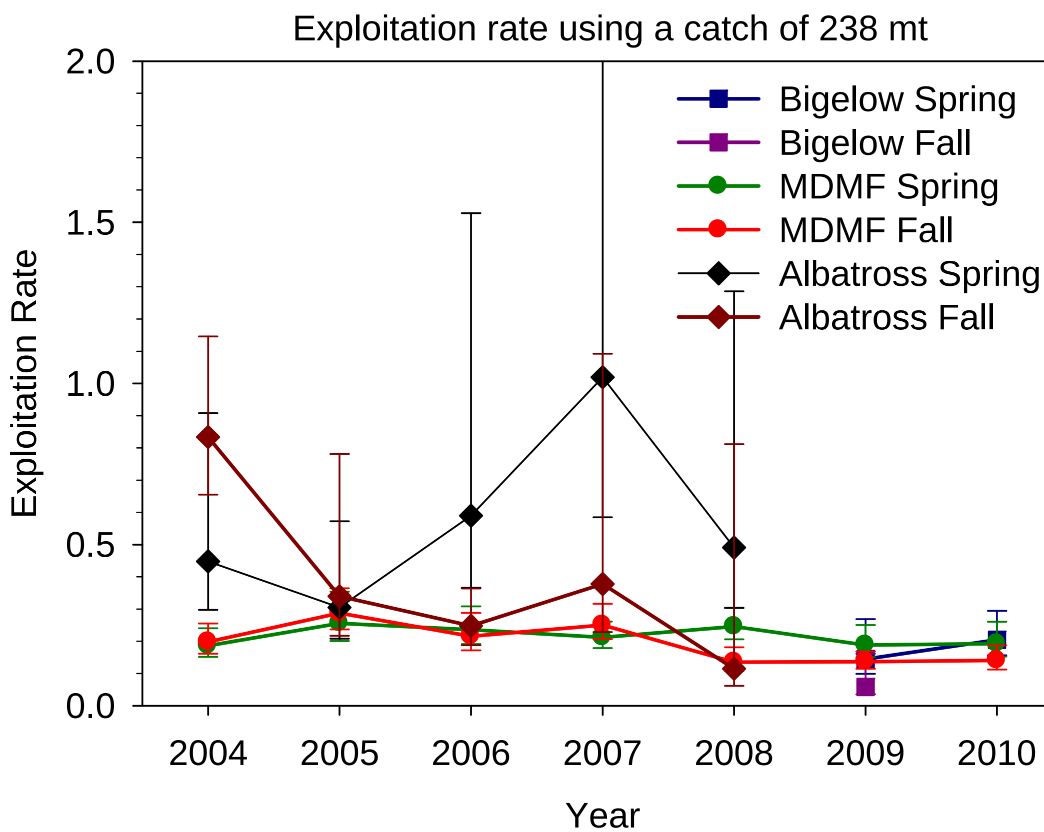
ME/NH Survey Spring



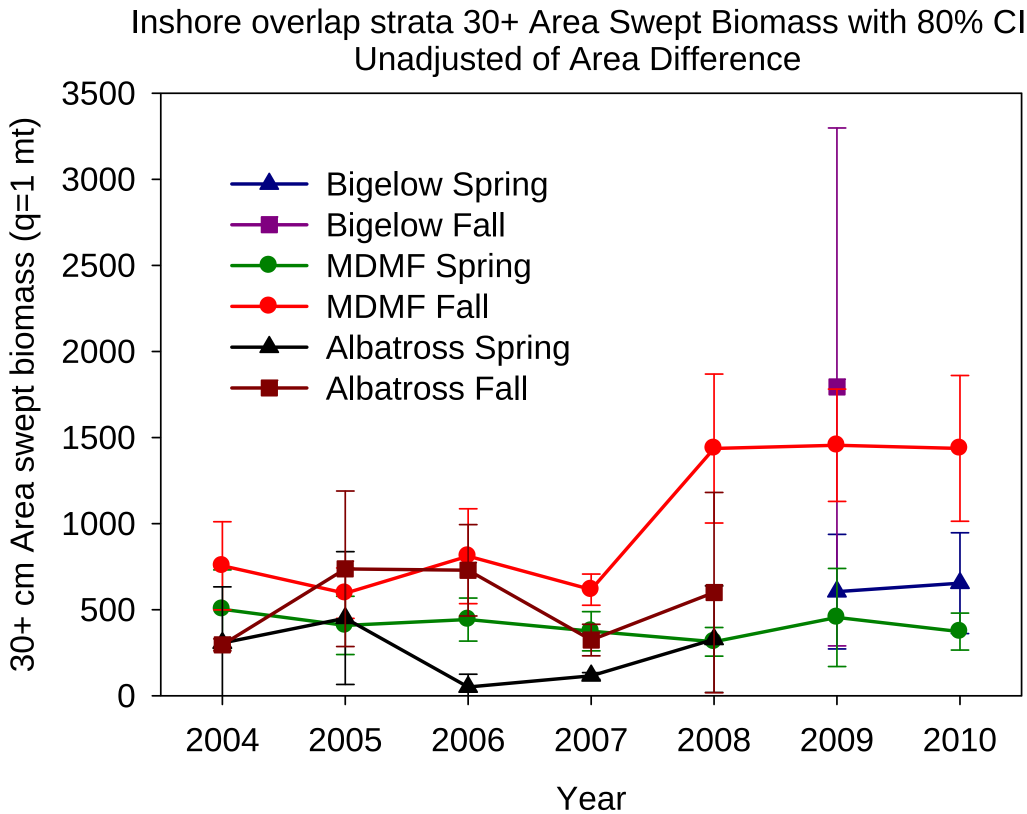
Appendix C1 Figure C5 - Numbers per tow at length from the inshore MENH survey. Relatively few fish 30 cm and greater are caught in the MENH survey.



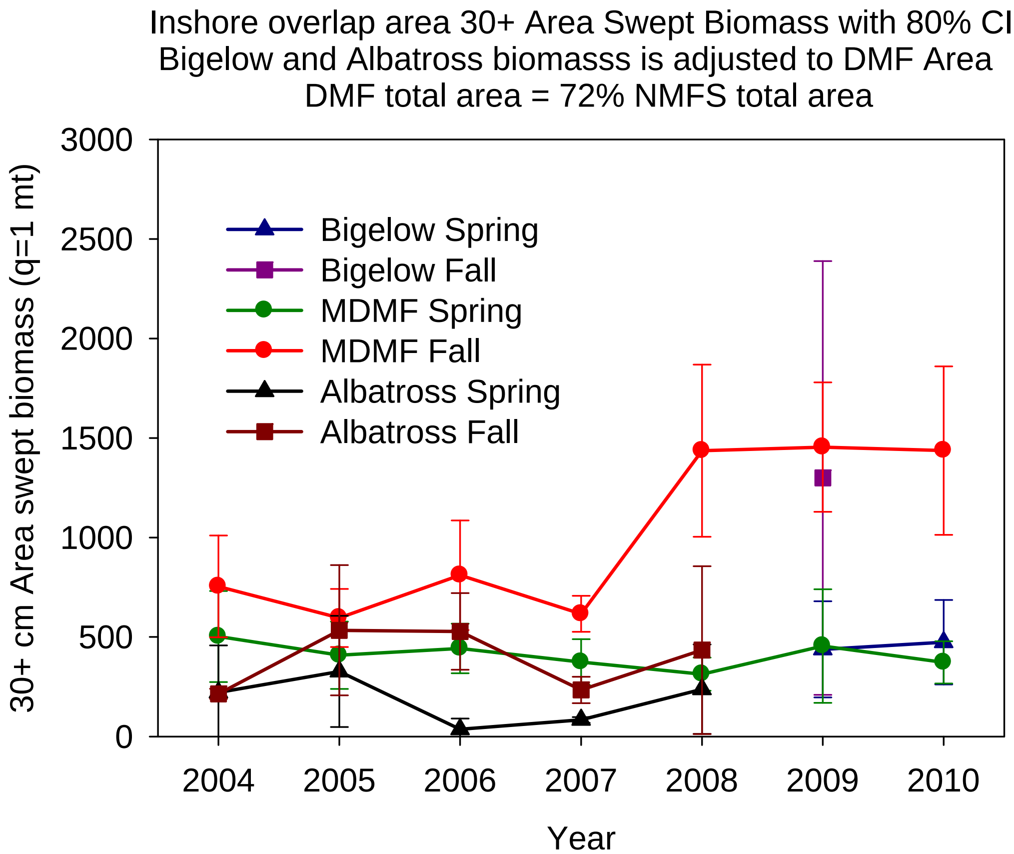
Appendix C1 Figure C6 - Minimum area swept exploitable biomass (30+cm) estimates by year with the associated 80% confidence intervals for the NEFSC (Albatross and Bigelow) and MDMF survey. Bigelow estimates were not adjusted to Albatross units.



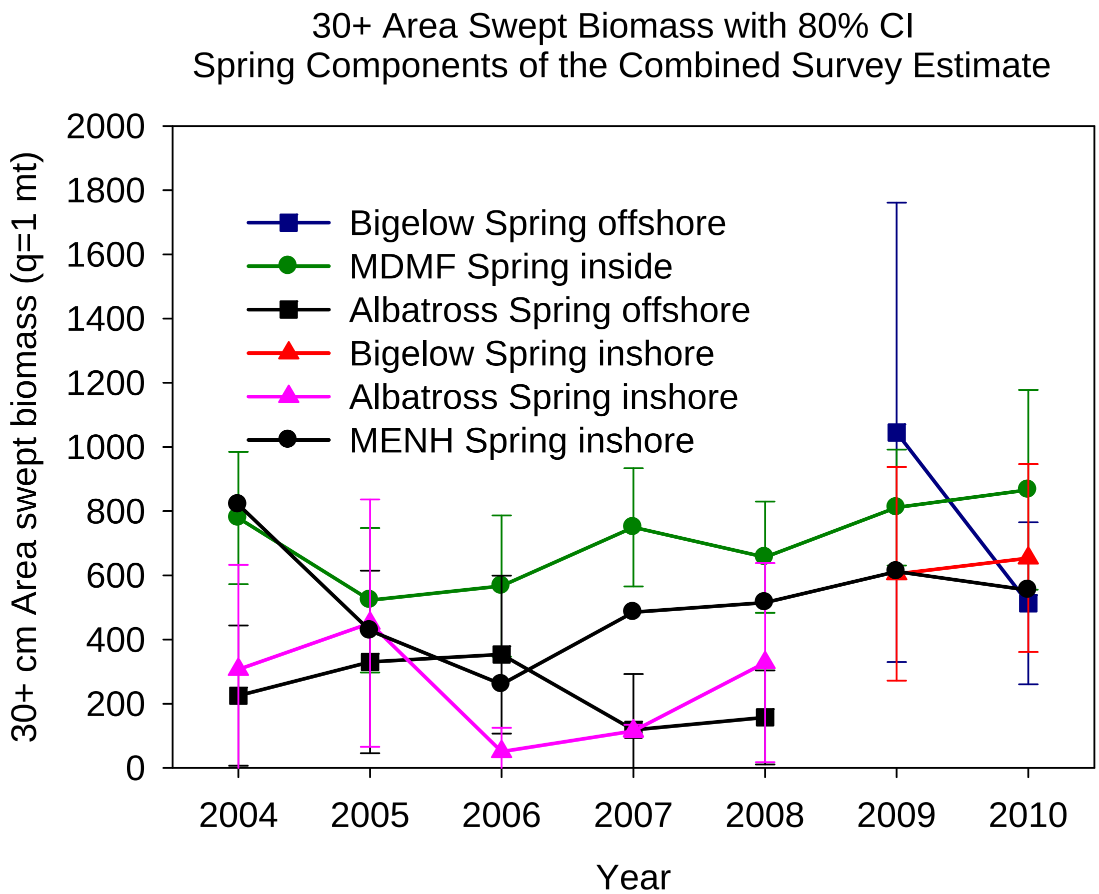
Appendix C1 Figure C7 - Exploitation rates assuming the ABC of 238 mt by year with the associated 80% confidence intervals for the NEFSC (Albatross and Bigelow) and MDMF surveys. Bigelow estimates were not adjusted to Albatross units.



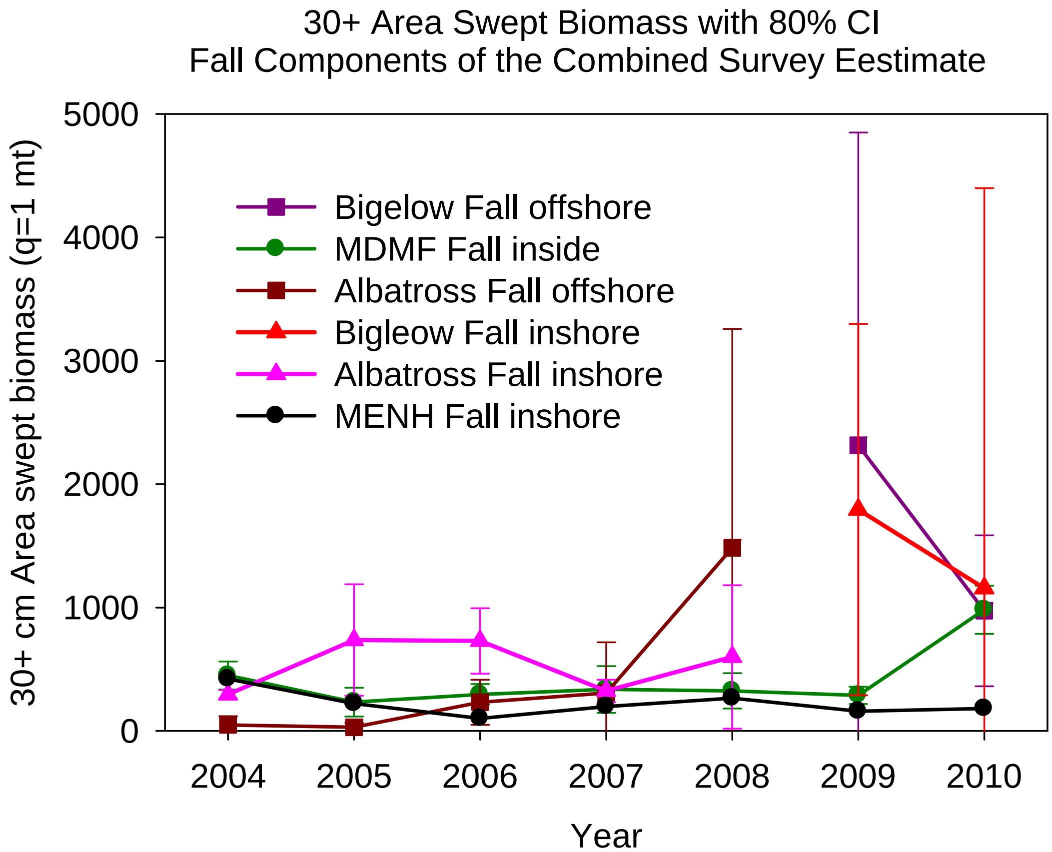
Appendix C1 Figure C8 - Minimum unadjusted area swept exploitable biomass (30+cm) estimates by year with the associated 80% confidence intervals limited to the overlap strata between the NEFSC (Albatross and Bigelow) and MDMF surveys. Bigelow estimates were not adjusted to Albatross units. NEFSC overlap strata equals 72% of the total DMF overlap area.



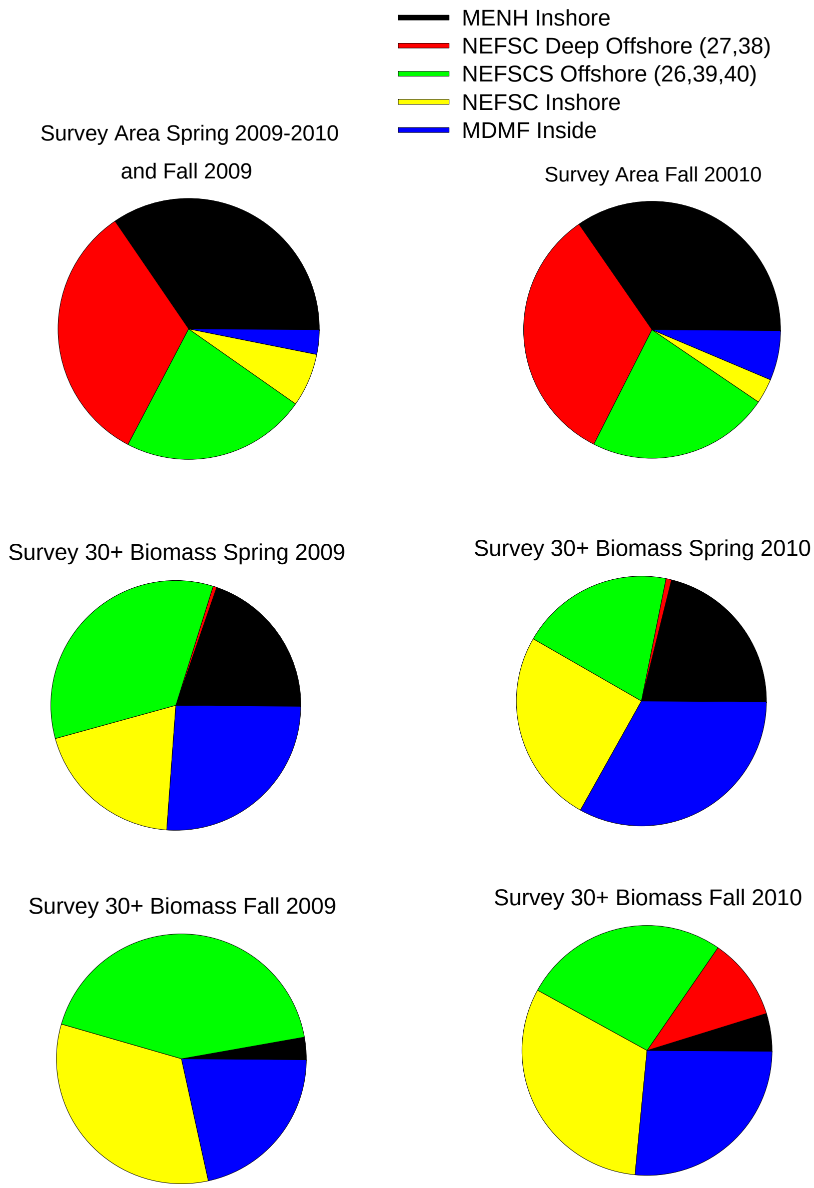
Appendix C1 Figure C9 - Minimum area adjusted area swept exploitable biomass (30+cm) estimates by year with the associated 80% confidence intervals limited to the overlap strata between the NEFSC (Albatross and Bigelow) and MDMF surveys. Bigelow estimates were not adjusted to Albatross units. NEFSC overlap strata equals 72% of the total DMF overlap area.



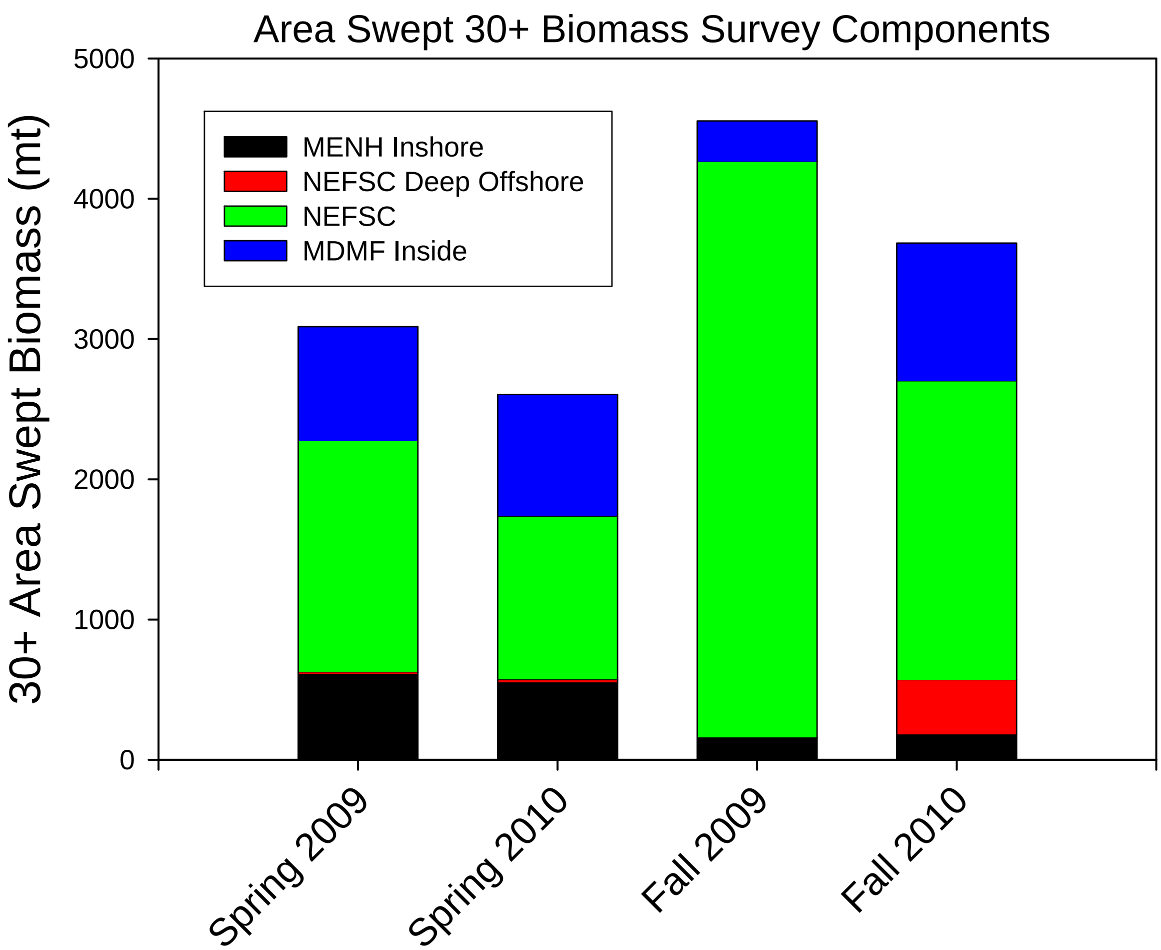
Appendix C1 Figure C10 - Spring minimum area swept exploitable biomass (30+cm) estimates by year with the associated 80% confidence intervals for the non-overlapping strata used in the combine biomass estimate. Bigelow estimates were not adjusted to Albatross units.



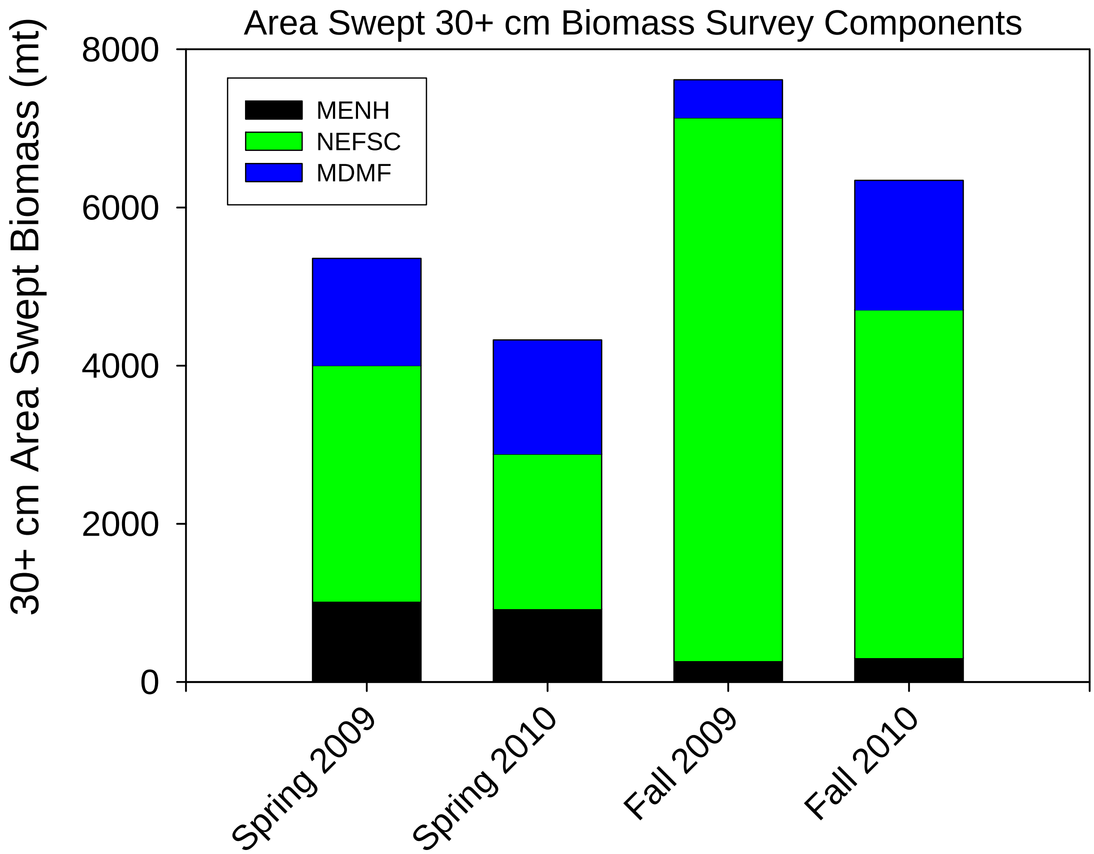
Appendix C1 Figure C11 - Fall minimum area swept exploitable biomass (30+cm) estimates by year with the associated 80% confidence intervals for the non-overlapping strata used in the combine biomass estimate. Bigelow estimates were not adjusted to Albatross units.



Appendix C1 Figure C12 –Pie charts of area coverage for each survey or NEFSC survey components (top). The Fall 2010 has a different area makeup due to the lack of coverage of Cape Cod Bay strata by the NEFSC survey. The estimated 30+ biomass for each component are shown for the spring 2009-2010 and fall 2009-2010 surveys.

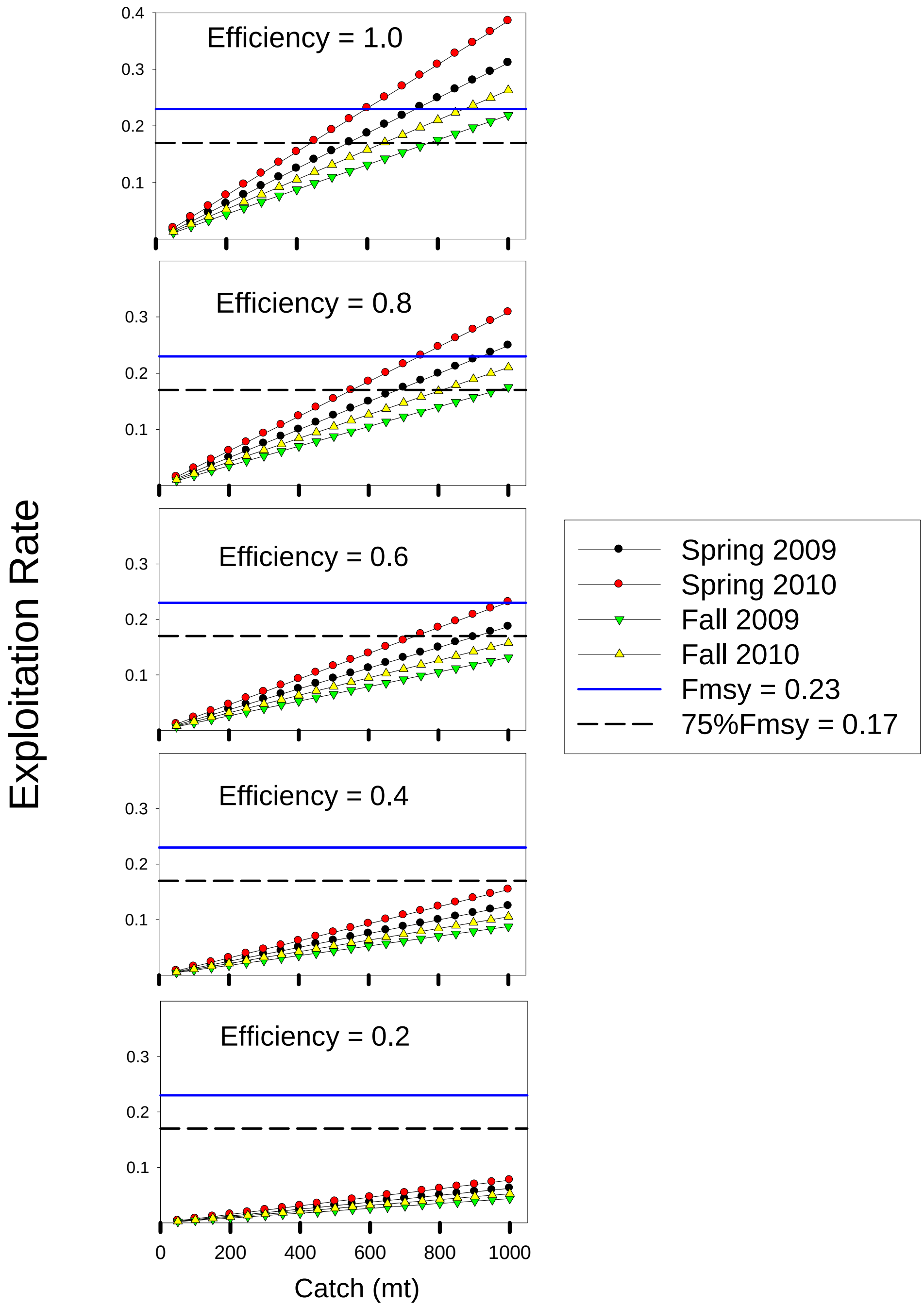


Appendix C1 Figure C13. 30+ area swept biomass estimates for the spring and fall surveys from 2009 to 2010 assuming efficiency is 1.0. The effect of using the NEFSC deep offshore strata (27, 38) can be seen in red. These strata were not used in the final estimates due to the lack of fish present in the deeper central part of the gulf of Maine.

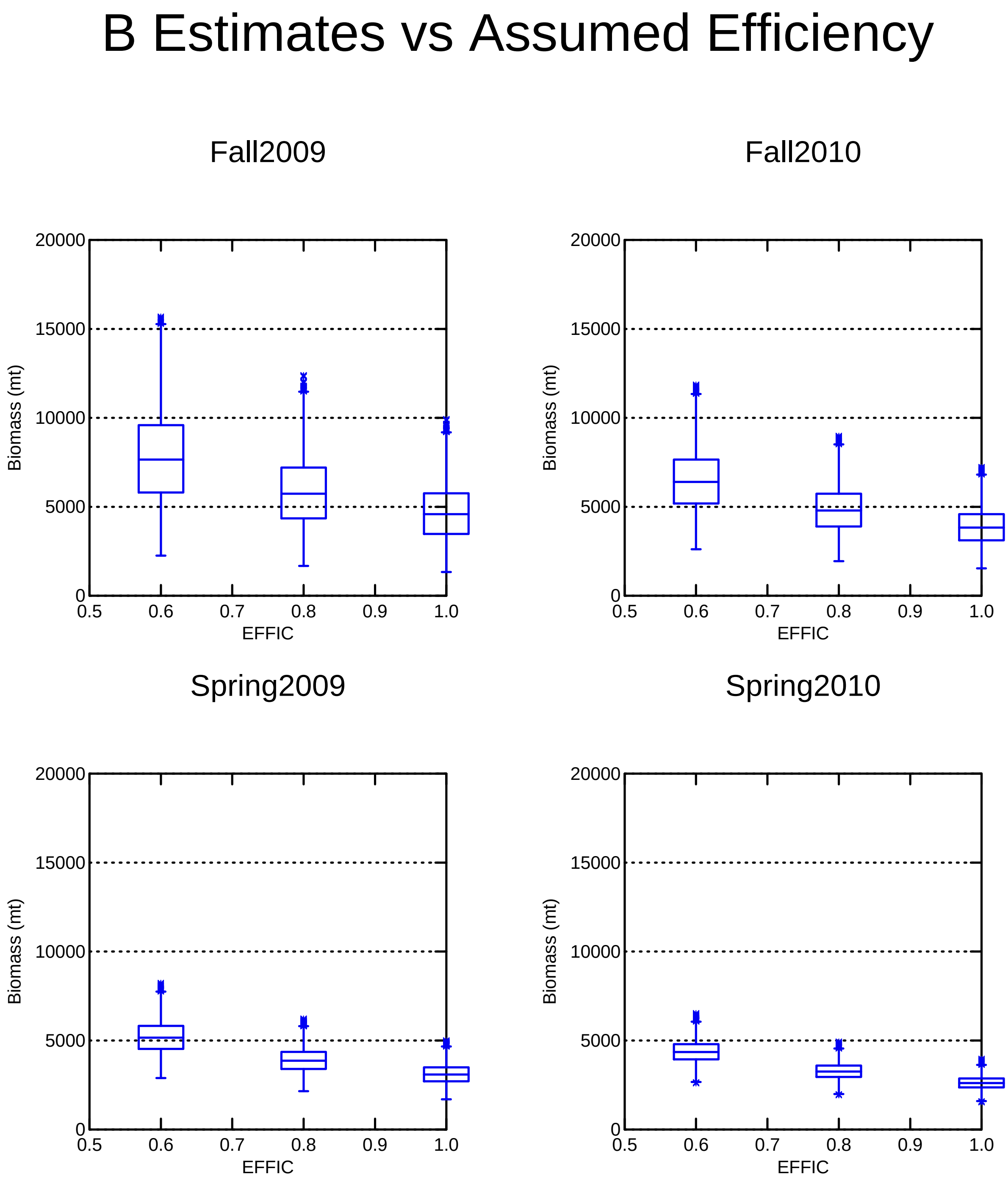


Appendix C1 Figure C14. The 30+ cm area swept biomass estimates for the spring and fall surveys from 2009 to 2010 assuming an efficiency of 0.6 which was used for overfishing status determination. The NEFSC survey used a TOGA tow criteria of 132x.

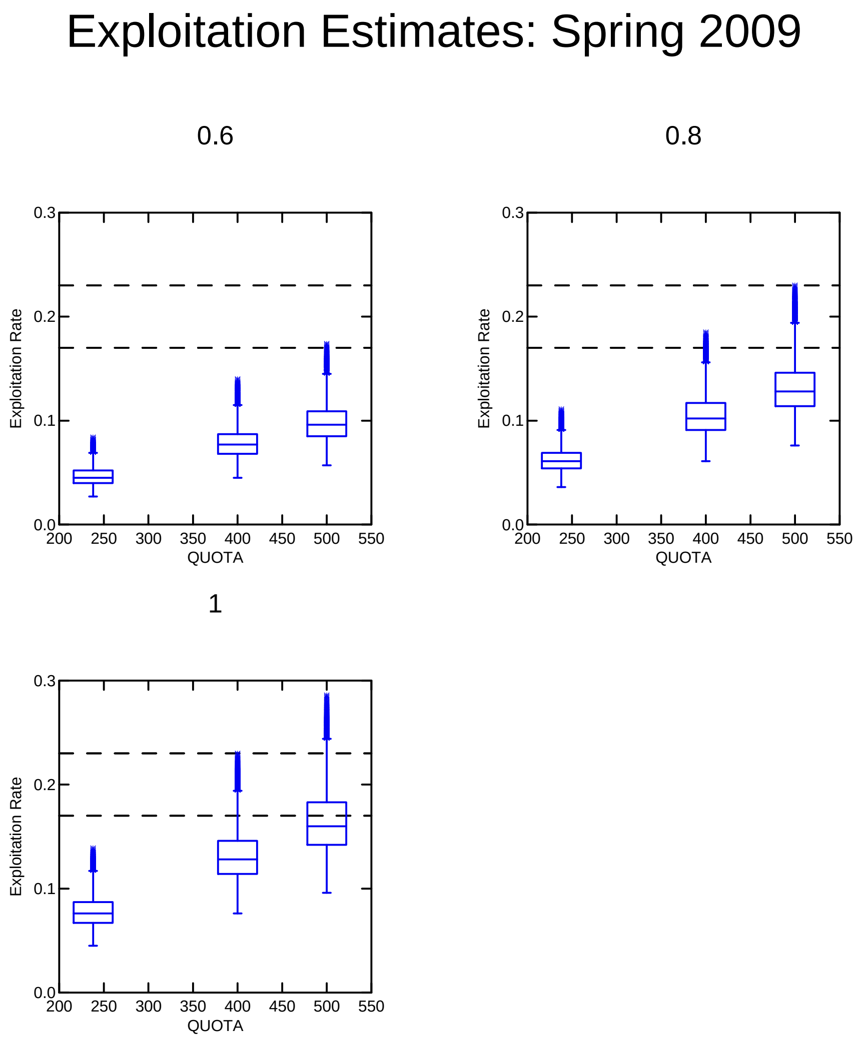
Appendix C1 Figure C15. Length based yield per recruit analysis using updated von Bertalanffy parameters estimated from the spring and fall 2006-2010 NEFSC surveys, maturity at length from the MDMF survey and assuming a natural mortality of 0.3. F40% was estimated at 0.31.



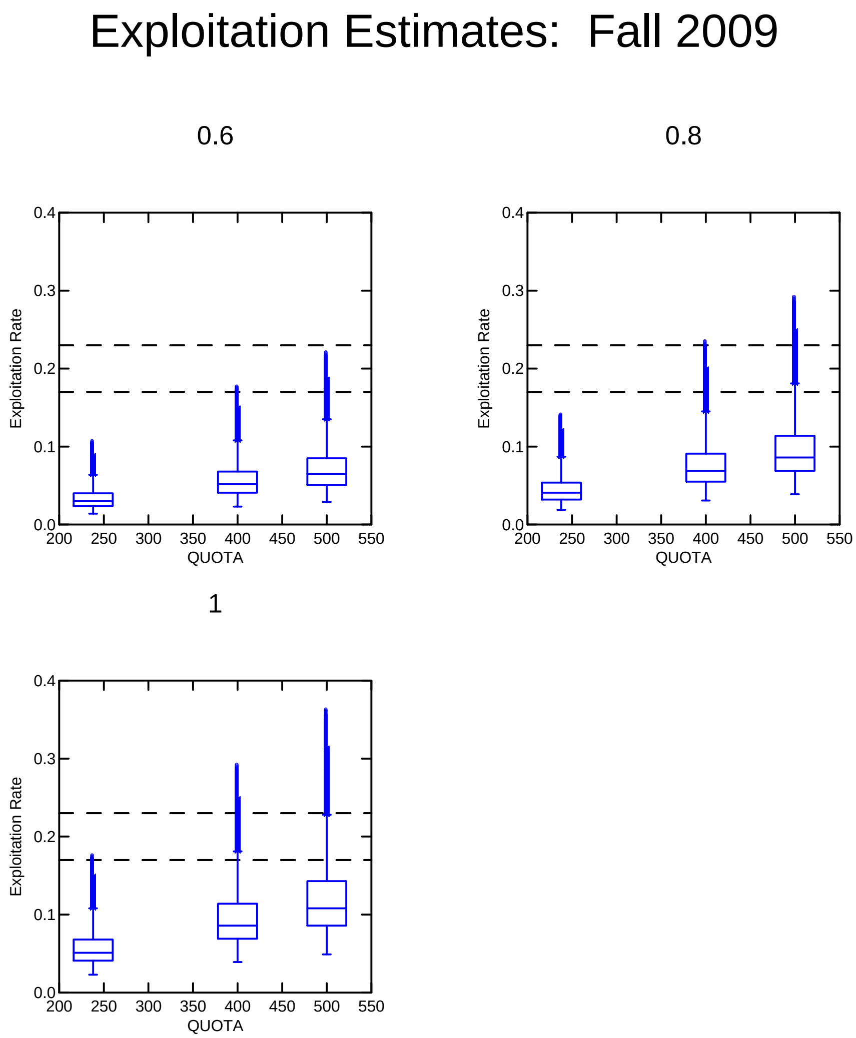
Appendix C1 Figure C16 - Exploitation rate (catch over survey biomass) for a range of catches using the combined surveys (spring and fall 2009 20010) assuming different efficiencies (0.2 to 1.0). Solid blue line is exploitation rate at Fmsy = 0.23 and the dashed black line is the exploitation rate at 75% F_{MSY} (0.17).



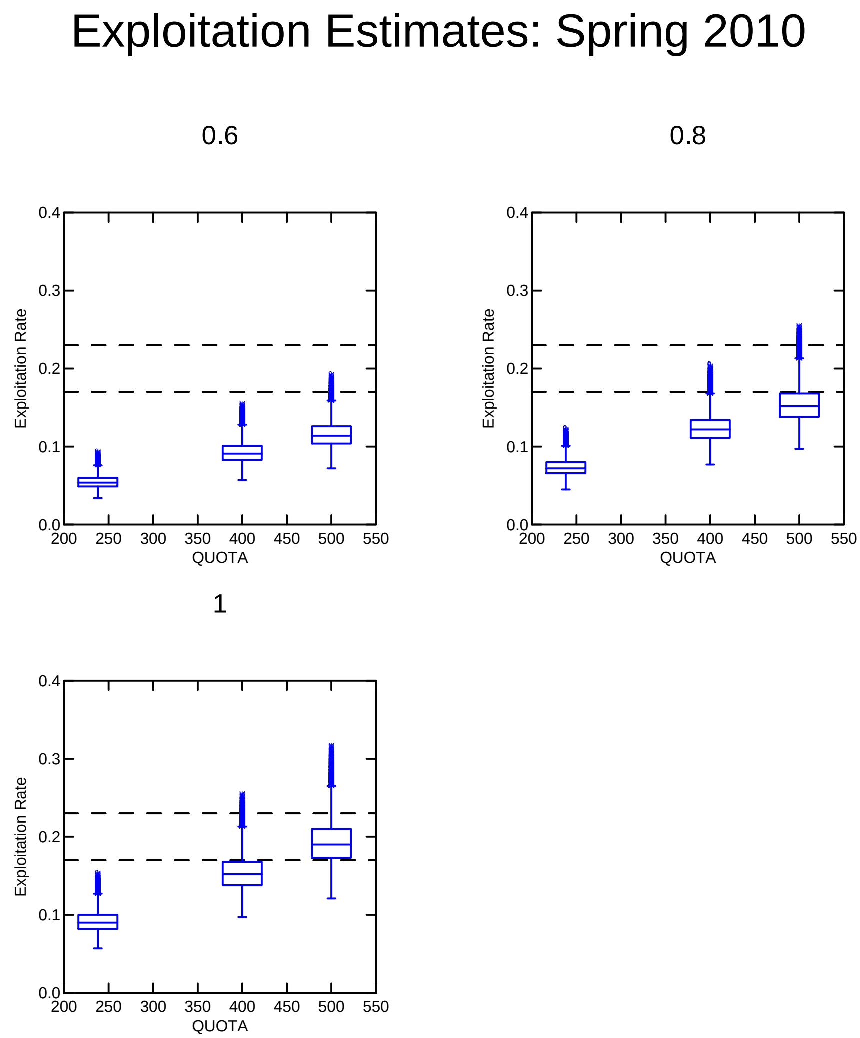
Appendix C1 Figure C17 - Sensitivity of swept area 30+ cm biomass estimates for Gulf of Maine winter flounder for varying seasons and years under three alternative assumed values of trawl efficiency for all three surveys.



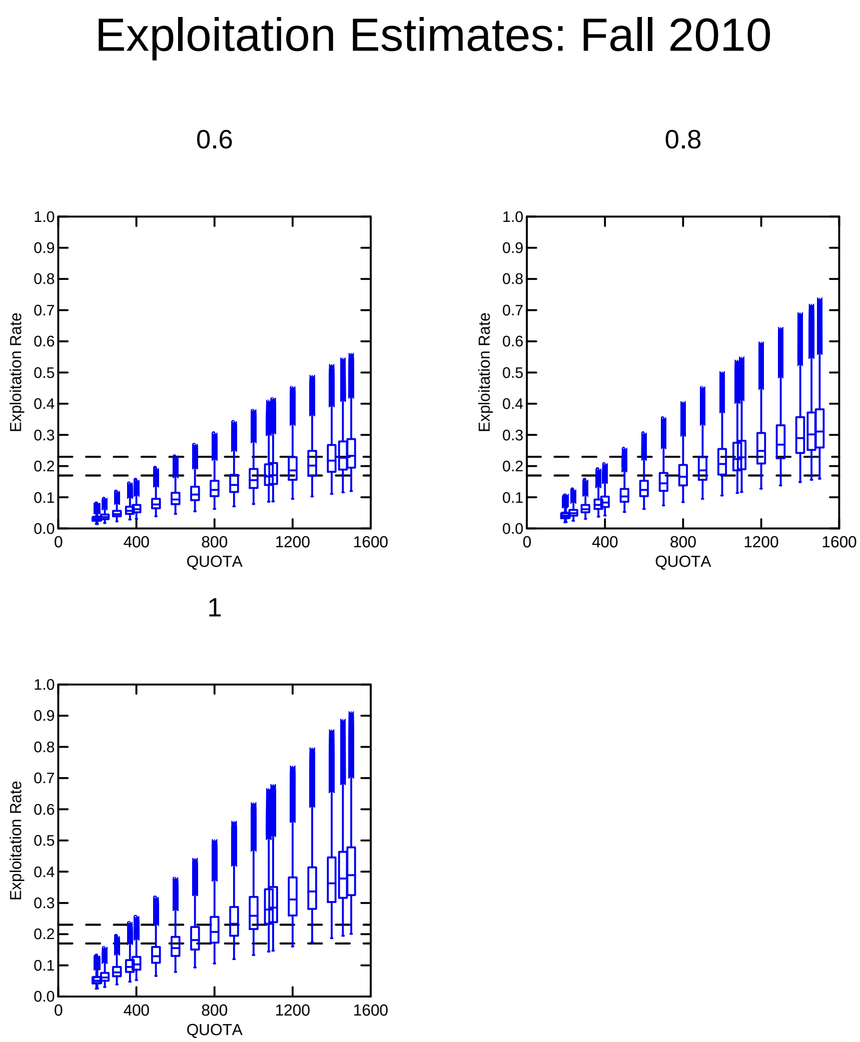
Appendix C1 Figure C18 - Estimated exploitation rates for Gulf of Maine winter flounder for spring 2009 based on three assumed estimates of gear efficiency (0.6, 0.8, and 1.0) and three assumed catch quotas of 238, 400, and 500 mt. Dashed lines represent length based estimates of F40% and 75% of F40% expressed as exploitation rates (0.23 and 0.17). SSB per recruit is derived using GOM winter flounder growth and maturation relationships and an assumed knife edge selection curve at 30 cm.



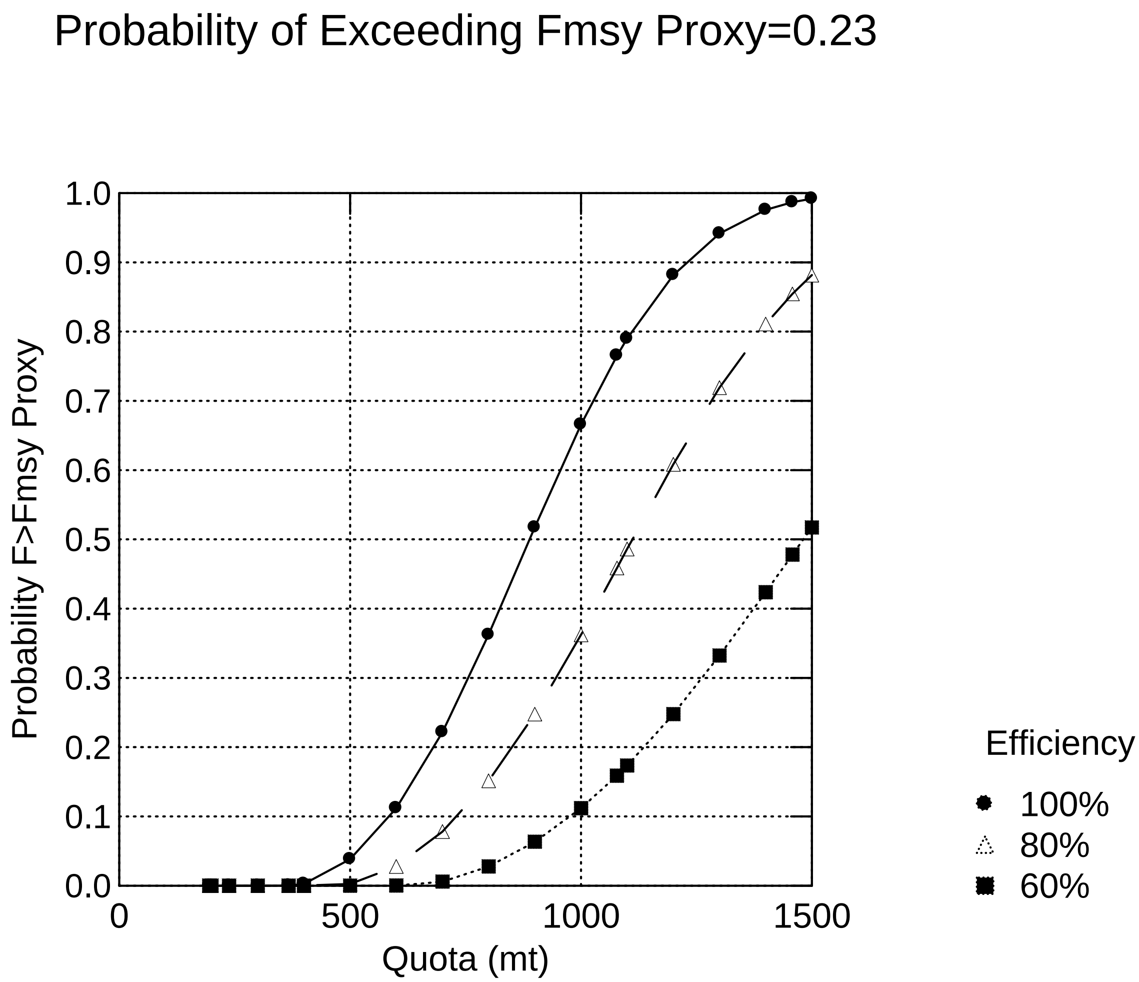
Appendix C1 Figure C19 - Estimated exploitation rates for Gulf of Maine winter flounder for Fall 2009 based on three assumed estimates of gear efficiency (0.6, 0.8, and 1.0) and three assumed catch quotas of 238, 400, and 500 mt. Dashed lines represent length based estimates of F40% and 75% of F40%expressed as exploitation rates (0.23 and 0.17). SSB per recruit is derived using GOM winter flounder growth and maturation relationships and an assumed knife edge selection curve at 30 cm.



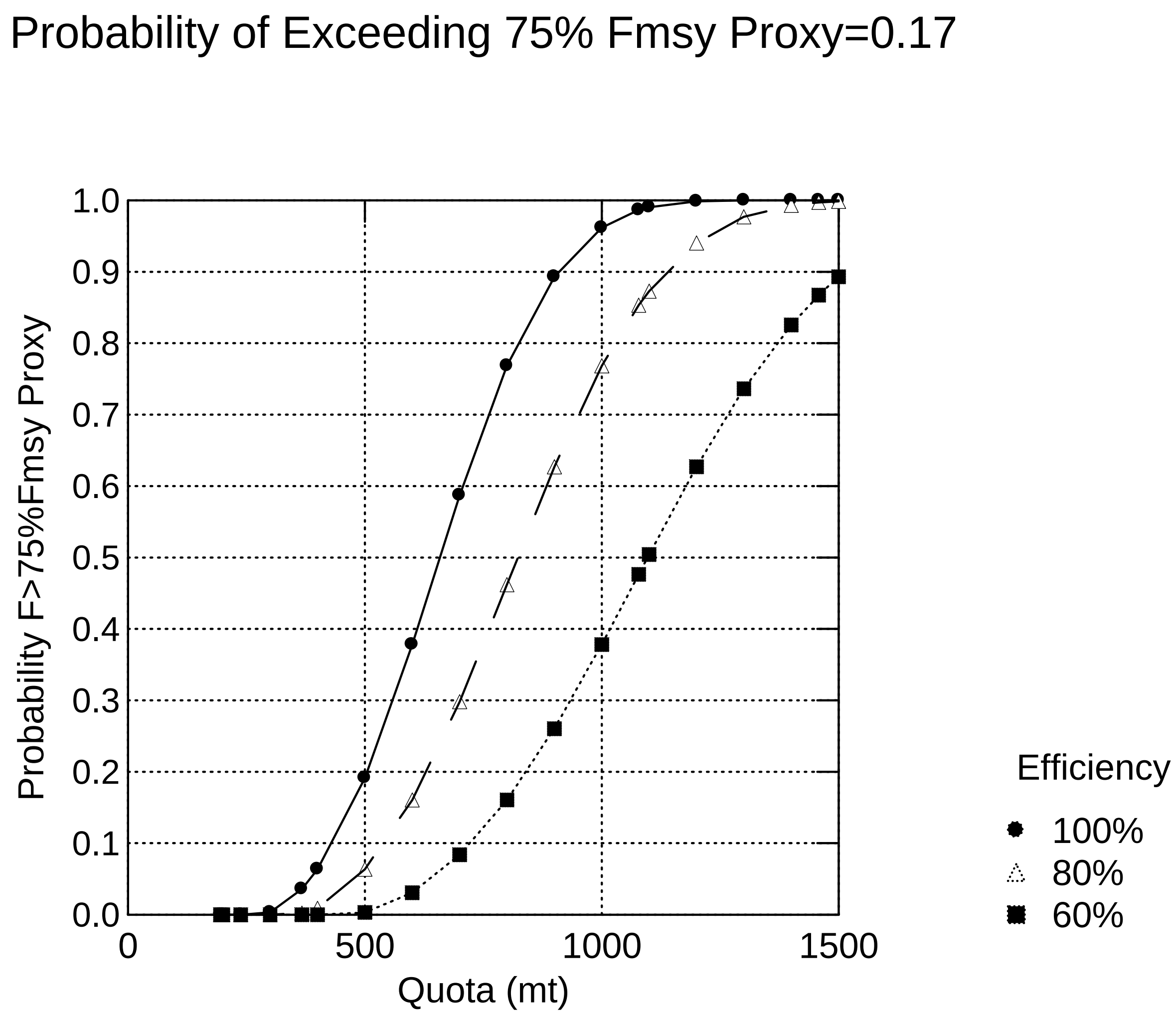
Appendix C1 Figure C20 - Estimated exploitation rates for Gulf of Maine winter flounder for Spring 2010 based on three assumed estimates of gear efficiency (0.6, 0.8, and 1.0) and three assumed catch quotas of 238, 400, and 500 mt. Dashed lines represent length based estimates of F40% and 75% of F40% expressed as exploitation rates (0.23 and 0.17). SSB per recruit is derived using GOM winter flounder growth and maturation relationships and an assumed knife edge selection curve at 30 cm.



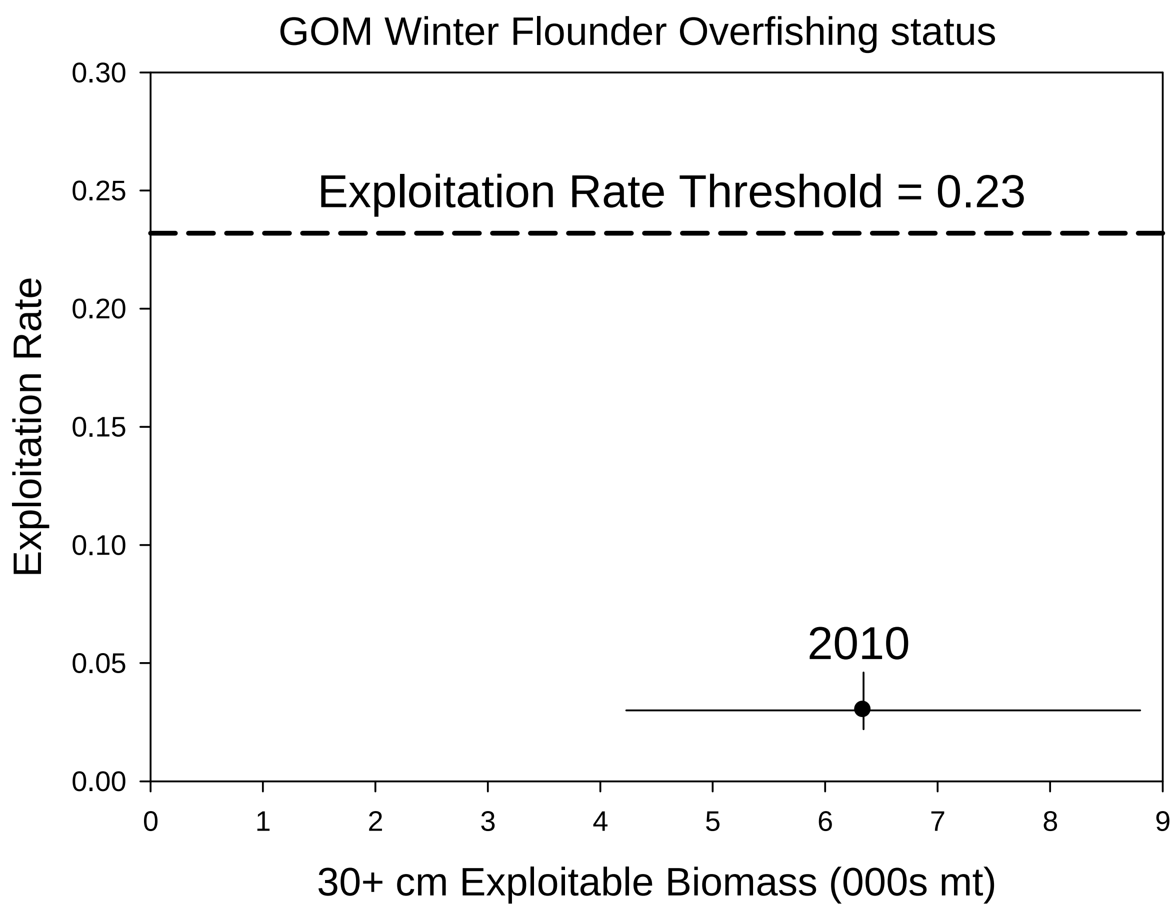
Appendix C1 Figure C21. Estimated exploitation rates for Gulf of Maine winter flounder for Fall 2010 based on three assumed estimates of gear efficiency (0.6, 0.8, and 1.0) and the 2010 catch of 195 mt, an assumed quota of 500 mt, 700 mt, 75% OFL of 1,078 mt and the OFL of 1,458 mt based on F40%. Dashed lines represent length based exploitation rate estimates of F40% (0.23) and 75% of F40% (0.17). SSB per recruit is derived using GOM winter flounder growth and maturation relationships and an assumed knife edge selection curve at 30 cm.



Appendix C1 Figure C22. Estimated probability of exceeding FMSY (F40 proxy) of 0.23 expressed as an exploitation rate assuming efficiencies of 60%, 80% and 100% base of the fall 2010 surveys across a range of quotas.



Appendix C1 Figure C23. Estimated probability of exceeding 75% of FMSY (F40 proxy) of 0.17 expressed as an exploitation rate assuming efficiencies of 60%, 80% and 100% base of the fall 2010 surveys across a range of quotas.



Appendix C1 Figure C24. Stock status for GOM winter flounder in 2010 with respect to MSY-based BRPs; error lines are 80% confidence intervals. F40% of 0.31 corresponds to an exploitation rate of 0.23.

Appendix 1 to the SAW52 Assessment Report.

The following is an excerpt from:

52th Northeast Regional Stock Assessment Review Committee
6 – 10 June 2011
Northeast Fisheries Science Center
Wood's Hole, MA

SARC 52 SUMMARY REPORT

DRAFT 29 June 2011

Review Committee
Patrick J. Sullivan (chair)
Noel Cadigan
John Casey
Cynthia Jones

Appendix 1.

The Review Committee and NEFSC scientists developed a method at the meeting for combining information on winter flounder across regions to help inform the spawner-recruit relationships used in developing projections and Biological Reference Points. The method is described below and uses likelihood-based AIC methods to find a reasonable compromise between a spawner-recruit relationship based on combined data sources and the individual spawner-recruit estimates associated with the individual stocks of winter flounder. This method maximizes the fit to both the SNE/MA and GBK datasets while minimizing the differences between relationships in the adjoining regions.

FMSY, SSBMSY, and MSY were estimated using a spawner-recruit model applied over a range of values for steepness (defined as the slope of the stock recruitment curve near the origin). It was assumed, based on the biology of the species, that steepness should be similar between the different stocks. These stocks are neighbouring populations of the same species that share common reproductive strategies. Fecundities at size are similar, although larval survivorship and recruitment to the fishery may vary between areas. Because the data available for any one stock may not be sufficient to fully parameterize a spawner-recruit relationship, some method of bringing additional information to bear on the estimates would be useful. Initially estimates of steepness from the work of Myers et al. (1999) were used as a prior for estimating the spawner-recruit relationship, but because the Myers et al. data include only more distantly related Pleuronectids than those present in these assessments it was felt that some way of using information available in the adjacent stocks would be more appropriate.

The objective was to find values of steepness chosen to be as similar as possible between stocks within the constraints of the information content available within each stock. A strategy was outlined that allowed the steepness parameters to be chosen among a range of values that provided reasonable fits to the spawner-recruit data for each individual stock, but were also reasonably close in the parameter space to each other. A profile of ΔAICs for each spawner-recruit model was developed from each of the two available stocks. The profiles are provided in Figure 1 below. It was considered that values of steepness associated with the AIC values that are within 2 units of the minimum AIC for each stock would be within a range of realistic values (Burnham and Anderson, 2002).

Once the profiles were generated, the fit for a given stock that resulted in the AIC that was closest to the minimum AIC value from the opposite stock was chosen within the constraint that the choice was not outside the ΔAIC = 2 bound for the given (original) stock's minimum fit. For the SNE stock this means steepness was set at the largest value possible within ΔAIC = 2 of its minimum fit (steepness = 0.61). For the GBK stock this means steepness was set at the smallest value such that ΔAIC = 2 of its minimum fit (steepness=0.78). Thus, the model estimates were shrunk towards each other, making steepness as similar as possible without losing the stock specific characteristics of the recruitment process.

The BRP estimates derived for the winter flounder stocks based on the spawner-recruit relationship specified in this way are direct MSY-based estimates and we believe are the most appropriate for use in informing management decisions at this time.

Burnham, K. P., and Anderson, D.R. 2002. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach, 2nd ed. Springer-Verlag.

Myers, R. A., Bowen, K. G., Barrowman, N. J. 1999. Maximum reproductive rate of fish at low population sizes. Can. J. Fish. Aquat. Sci. 56: 2404-2419.

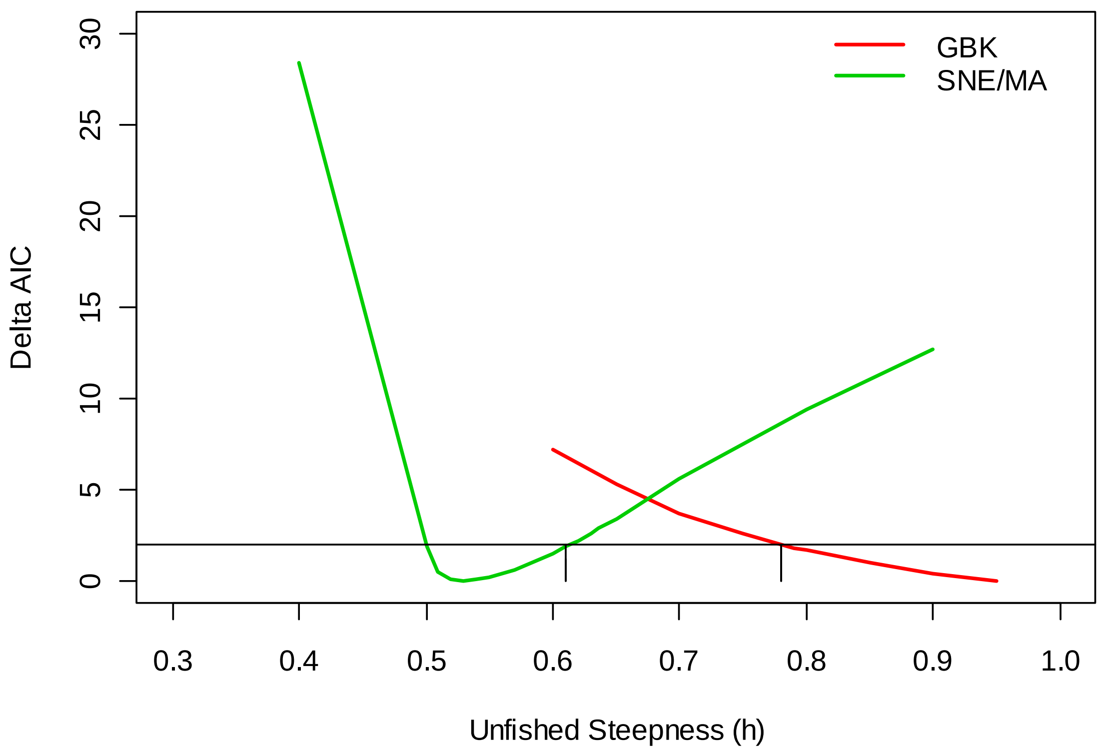


Figure 1. Delta AIC (AIC – min(AIC)) for each region's fitted spawner-recruit relationship over a range of fixed steepness parameter values. The curves correspond to the AIC values from the fits for the two regions (Georges Bank and Southern New England / Mid-Atlantic). The black horizontal line corresponds to the Delta AIC threshold of 2. Steepness values corresponding to an AIC below 2 are not considered statistically different from one another with a region. The vertical black lines show the locations of the most similar steepness parameters that are still within the range of best estimates for each model. The steepness values corresponding to this criteria are 0.61 for SNE/MA and 0.78 for GBK.

Appendix 2 to the SAW/SARC-52 Assessment Report.

[SAW52 Editor's Note: This Appendix 2 contains many, but not all, of the Working Papers that were developed and/or considered by the SAW Working Group during its meetings before the SARC peer review. As such, these WPs do not necessarily contain final results. They are included to serve as background materials to the final Assessment Report.]

Quick List of WP's in Appendix 2:

1. Stock structure
2. Survey strata sampling
3. Fish maturity schedule
4. Stock structure
5. Catch allocation
6. Management regulations
7. Length-based survey calibration
8. Fish maturity methods

9a. and 9b. VMS stock apportionment

10. Industry-based survey
11. Discard rate estimates
12. Fish reproductive potential
13. Environmental stock-recruit models
14. Uncertainty in trip-based allocated landings
15. M from tagging study
16. Biological Reference Points and stock vulnerability (also called WP_D_16)
17. SCAA Model - SNEMA (Rademeyer and Butterworth)
18. SCAA Model Update - SNEMA (Rademeyer and Butterworth)
19. SCAA Model - GOM (Rademeyer and Butterworth)

An Interdisciplinary Assessment of Winter Flounder (*Pseudopleuronectes americanus*) Stock Structure

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Keywords: winter flounder, Pseudopleuronectes americanus, stock identification, stock structure

Abstract

An interdisciplinary review was undertaken to evaluate the stock structure and management of winter flounder (*Pseudopleuronectes americanus*) throughout its geographic range in the northwest Atlantic. Information on morphology, tagging studies, genetics, larval dispersal, life history traits, environmental signals and meristics was considered. In the coastal waters of the United States, winter flounder are managed as three separate units; Georges Bank, Gulf of Maine and Southern New England/Mid-Atlantic. In Canadian waters, winter flounder are managed as three units: western Scotian Shelf (NAFO Div. 4X), eastern Scotian Shelf (NAFO Div. 4VW), and the southern Gulf of St. Lawrence (NAFO Div. 4T). Estuarine spawning, which likely plays an important role in reproductive isolation and population structure, is non-existent on Georges Bank and Browns Bank, variable in more northern habitats and may be obligate in southern New England. Contingent groups are likely present in several regions, and merit further research. Despite evidence for local population structure, information from tagging, meristic analysis, and life history studies suggest extensive mixing within stock units, thereby supporting the current U.S. management regimen. Genetic analysis and parasite markers indicate that Canadian management units are distinct. However, examination of inshore and offshore winter flounder within division 4X suggests little interchange occurs between these groups. Based on their distribution and life history traits, several flounder stocks likely exist within the 4T management area. A stock composition analysis of mixed-stock fisheries would be useful to facilitate the management and assessment of winter flounder in both U.S. and Canadian waters.

Introduction

Accurate stock assessment and effective fishery management requires identification of self-sustaining groups within species. Stock identification involves interdisciplinary analysis of life history information, genetics, geographic variation of phenotypic traits, movement and environmental signals (Cadrin, et al., 2005). Advances in several of these disciplines warrant reanalysis and re-evaluation of stock structure as new information arises (Begg and Waldman, 1999).

Although stock identification techniques have been used in fisheries science for over a century, no consensus has been reached on how to best define a unit stock (Waldman, 2005a). Early definitions of the term stock were based on utilization by fisheries. More recent definitions of fish stocks have focused on demographics, and imply that a degree of spatial and temporal discreteness is needed for a stock to evolve (Waldman, 2005a). Hilborn and Walters (1992) defined a stock as an arbitrary group of fish large enough to be essentially self-reproducing, with members of each group having similar life history characteristics. Booke (1981) stated that socks can have either a genetic basis or a phenotypic basis, in which the expression of life history characteristics are dependent upon the environment.

Stock assessment models assume that individuals within a stock exhibit homogenous vital rates and life cycle closure (Cadrin et al., 2005). Therefore, well informed stock boundaries are necessary to manage and assess fish stocks accurately. For example, if two distinct biological stocks are managed as a single unit, a common catch limit (or Total Allowable Catch) may lead to the overexploitation of the less productive component, and the under utilization of the more productive component (Ricker, 1958). Problems with assessment models can also arise (i.e., retrospective patterns), when landings from a fishery are classified to the wrong stock area.

Stock identification studies that utilize multidisciplinary methods typically produce the most accurate results (Coyle, 1998). Certain approaches (i.e., meristics and microsatellite markers) can be used to detect for differences in fish stocks that may have arisen in the recent past, while other techniques (i.e., allozymes, coding DNA) are more conservative, and require longer periods of isolation to become recognizable between different stocks. An interdisciplinary approach also creates a more robust baseline, making more techniques available for use in subsequent stock composition analyses.

Winter flounder are found in coastal waters (0-125m) of the Northwest Atlantic from North Carolina, northward to Newfoundland (Figure 1; Bigelow and Schroeder, 1953; McCracken, 1963; Pereira et al., MS 1999; Collette and Klein-MacPhee, 2002), and the distribution of this species is centered between New Jersey and Nova Scotia (Perlmutter, 1947). Winter flounder are managed as three stocks in U.S. coastal waters; Gulf of Maine, Georges Bank, and Southern New England/Mid-Atlantic (SNE/MA; Figure 2; NEFSC 2003). The winter flounder resource is managed as three units in Canadian waters (Figure 3): (1) Browns Bank, St. Marys Bay and Bay of Fundy winter flounder are managed concurrently in NAFO Div. 4X; (2) winter flounder from the Scotian Shelf and points eastward are managed together in NAFO Div. 4VW; and (3) winter flounder are managed as one unit in the Southern Gulf of St. Lawrence in NAFO Div 4T. Winter flounder are present in coastal waters around Newfoundland (NAFO Div. 3), but due to sparse data and a limited directed fishery, this species is not managed under a catch limit in this area (DFO, MS 1996).

The stock structure of winter flounder has been investigated since the early 1900's (e.g., Kendall, 1912; Lobell, MS 1939). Early research on winter flounder was focused primarily on migration, life history rates and analysis of meristic characters. Over time, more disciplines such as genetics, parasitic characters and hydrodynamic modeling were used to investigate winter flounder stock structure. Currently, newer methods such as otolith chemical analysis (Jackman et al., MS 2010) and telemetry tagging are being used to better understand the stock structure of winter flounder.

The objective of this review is to synthesize information on the stock structure of winter flounder (*Pseudopleuronectes americanus)* throughout its geographic range by reviewing benchmark case studies from a variety of disciplines. The synthesis is used to assess the appropriateness of current management protocols in both the United States and Canada, based on the available scientific information. In regions where stock boundaries are uncertain, opportunities for future research are discussed.

Review of Stock Identification Information

Life History Traits

Dispersal of early life stages- Winter flounder exhibit relatively isolated metapopulation structure in the bays and estuaries along the east coast of North America (Perlmutter, 1947; Saila, 1961). This species spawns adhesive and demersal eggs (Klein-MacPhee, 1978), which limits dispersion. Larvae are pelagic, and undergo metamorphosis after an average of two months in the water column (Chambers and Leggett, 1987). Larvae which are bottom-oriented and negatively buoyant, have been observed to be more abundant near the benthos (Pearcy, 1962; Klein-MacPhee, 1978).

Pearcy (1962) studied the Mystic River estuary in Connecticut, and found that while net transport in the estuary was seaward, transport in the bottom layers of the estuary was landward. Pearcy (1962) found that larvae can control their vertical position in the water column in relation to the tide, which will promote retention within estuaries and allow juveniles to settle in close proximity to their hatching site. Hydrodynamic modeling studies have estimated that rates of larval retention in estuaries is likely high (Crawford and Carey, 1985; Chant et al., 2000). Thus, estuarine spawning and nursery grounds appear to be closely linked (Pearcy, 1962; Pereira et al., MS 1999). However, the fate of larvae spawned in coastal and offshore areas is poorly studied, and warrants further attention (i.e., DeCelles et al., MS 2010).

Life History Traits- Population parameters such as growth and age at maturity can be used to distinguish among discrete stocks of fish because these parameters are phenotypic expressions of the interaction between genotypic and environmental influences (Begg, 2005). Life history parameters for winter flounder have been derived using both fishery dependent and fishery independent sources of data. Winter flounder exhibit faster growth rates in southerly latitudes, and females typically grow faster and attain larger sizes than males (Table 1).

Analysis of scale annuli patterns (Lux, 1973) and tagging data (Howe and Coates, 1975) found that winter flounder on Georges Bank exhibit faster growth rates than the SNE/MA and Gulf of Maine stocks. Results from a common garden experiment suggest that the rapid growth exhibit by Georges Bank winter flounder has a genetic basis (Butts and Litvak, 2007). Based on tag return data (Howe and Coates, 1975) and aged scale samples (Witherell and Burnett, 1993), flounder in the SNE/MA stock area have been shown to grow slightly faster than in the Gulf of Maine (Figures 4 and 5). However, Berry et al. (1965) calculated slower growth rates for winter flounder in Narragansett Bay, RI.

Growth rates of winter flounder in Canadian waters have a similar latitudinal gradient. Winter flounder have been observed to grow faster in the 4X stock area than in the 4T stock area (Figure 6). Growth rates within the 4T area are dynamic, as winter flounder in the northern Gulf of St. Lawrence (St. Lawrence Estuary) were shown to exhibit slower growth than flounder in the Southern Gulf of St. Lawrence (Figure 6; McCracken, 1954; Vaillancourt et al., 1985). Fraboulet et al. (2009) captured spawning flounder from three regions in Canada: Passamaquoddy Bay, Chaleur Bay, and the St. Lawrence estuary. Common garden experiments showed that larval growth rates had a paternal component, and that larvae sired by males from the St. Lawrence estuary exhibited the slowest growth rates.

Winter flounder exhibit a clinal gradient in maturity at age throughout their geographic range, with individuals maturing faster in more southerly latitudes (Collette and Klein-MacPhee, 2002). Estimates of age and size at 50% maturity of winter flounder are depicted in Table 2. Differences in the timing and location of spawning events are useful stock identification criterion because they can lead to reproductive isolation among stocks by reducing gene flow (Bailey et al., 1999). Winter flounder exhibit a latitudinal gradient in time of spawning. While peak spawning times vary interanually, spawning typically occurs earlier in southern latitudes (Table 3).

Morphology

*Meristics- F*in ray counts have been used to investigate stock structure in winter flounder. Geographic variation in meristic characters, such as fin ray counts, between different stocks of fish suggest that there is little interchange between these stocks, and that reproductive isolation is possible. Meristic characters are the products of interactions between the genetics of an individual and its environment (Waldman, 2005b).

Kendall (1912) found that winter flounder from Georges Bank possessed significantly more fin rays than those from inshore regions, and initially described these offshore specimens as a new species (*P. dignabilis*). He also noted other morphometric differences, and described Georges Bank winter flounder as possessing shorter heads, different coloration and larger sizes than flounder taken inshore. Perlmutter (1947) calculated that winter flounder from the Georges Bank stock had significantly more anal, dorsal and pectoral fin rays than flounder from the SNE/MA and Gulf of Maine stocks areas. Lux et al. (1970) obtained similar findings for Georges Bank flounder using anal and dorsal ray counts. Lux et al. (1970) reported that adult winter flounder from the SNE/MA stock area had significantly more fin rays than those sampled from the Gulf of Maine. Pierce and Howe (1977) sampled young over the year winter flounder at 23 estuarine locations throughout Massachusetts waters. They also concluded that winter flounder in the SNE/MA stock possessed more fin rays than flounder in the Gulf of Maine. However, Pierce and Howe (1977) did not detect any significant differences in fin ray counts between estuaries, suggesting that individual estuaries do not contain unique stocks.

Environmental signals

Patterns of parasitic infestation- Parasites can be useful tools in stock identification studies. If a fish becomes infected with a parasite that has a known endemic range, it can be inferred that the fish was within that range within the life span of the parasite (MacKenzie and Abaunza, 2005). When groups of fish have unique parasitic characters, it can be inferred that there is limited movement of individuals between those groups.

Scott (1982) examined parasitological differences between winter flounder in the southern Gulf of St. Lawrence (NAFO area 4T) and the western Scotian Shelf (NAFO area 4X). Significant geographic variation was found between the two areas for three parasite species; *Derogenes varicus, Fellodistomum furcigerum* and *Lecithaster gibbosus*. Scott (1982) concluded that based on these parasitological characteristics, winter flounder in the Gulf of St. Lawrence and those on the western Scotian Shelf constitute separate stocks.

McClelland et al. (2005) examined 189 adult winter flounder from four geographic regions: St. Marys Bay, Georges Bank, Browns Bank, and Sable Island Bank. Seven parasite species were examined, including five species of digeneans and two species of larval nematodes. Individual fish could be identified to their sampling site with an 84% overall classification accuracy using a discriminant function analysis. Parasite characteristics provided evidence that the Georges Bank stock was distinct from groups of winter flounder in adjacent Canadian coastal waters.

Biochemical analysis- Similar to parasitic infestation, chemical contaminants can serve as acquired marks and be used to infer isolation or mixing among groups. Carr et al. (1991) sampled winter flounder at a polluted site (Boston Harbor, MA) and a relatively pristine control site (Plymouth Bay, MA). Carr et al. (1991) measured several biochemical parameters for each group of fish and found that about 50% of the fish collected in Boston Harbor had apparent apoptotic hepatic lesions (AAHPC), while lesions were not detected in any of the fish collected from Plymouth Bay. Other biochemical parameters (i.e., amino acid concentrations, glycogen levels) were also differed significantly between the two sites. Given the significant differences in chemical contamination between the two groups of sampled fish, it can be inferred that little or no interchange occurs between the two areas, despite their geographic proximity.

Gardner et al. (1989) examined the prevalence of liver disease in winter flounder collected at eight locations in the SNE/MA and Gulf of Maine stock areas. Flounder sampled offshore in the SNE/MA area (Martha's Vineyard) had low rates of liver disease (9%) while flounder from inshore locations such as New Bedford Harbor (57%) and Narragansett Bay (31-63%) had greater incidence of liver disease. In the Gulf of Maine stock, liver disease was prevalent in flounder sampled form Boston Harbor (83%), and less frequent in flounder captured in Cape Cod Bay (22%). While these studies were not conducted for stock identification purposes, chemical biomarkers have potential application to be used in examining stock boundaries for winter flounder.

Genetic analysis

Microsatellite Analysis- Microsatellite characters are currently the most suitable genetic tools used for stock identification research. Microsatellites have high genetic variation that can be detected at individual loci, can be analyzed relatively easily and there are a large number of loci that can be screened (Wirgin and Waldman, 2005).

Microsatellite studies of winter flounder in Canadian waters revealed the existence of at least four distinct stocks (McClelland et al., 2005). Mature winter flounder were sampled from four geographic locations; Georges Bank, Browns Bank, Sable Island Bank and St. Marys Bay, and analyzed using four microsatellite loci. The Georges Bank sample was found to be the most genetically distinct, while the Browns Bank and Saint Marys Bank samples had the least genetic dissimilarity. Fish were classified to their capture site with 86-96% accuracy using a discriminant function analysis.

Crivello et al. (2004) sampled winter flounder larvae from three spawning areas (Niantic, Thames and Westbrook rivers) in Long Island Sound, NY. Of the 18 tests conducted (six microsatellite loci at three sampling locations), 13 were found to deviate from the expected Hardy-Weinberg equilibrium. In addition, these differences were geographically based, with the greatest amount of genetic differences observed between the two most distant groups, and the least amount of difference between the two closest groups. These results suggest that local populations of winter flounder along the coats may be at least partially isolated from one another.

Gene expression- Fletcher and Smith (1980) and Fletcher et al. (1985) examined the timing of antifreeze protein formation and termination exhibited by winter flounder in four locations: Long Island, NY; Nova Scotia; Passamaquoddy Bay; and Newfoundland. Their research found that the timing of gene expression differed in populations between the four regions, and suggested that these differences may be genetically based, implying that the populations are distcinct. Hayes et al. (1991) analyzed the copy number and arrangement of antifreeze protein genes in winter flounder from nine locations. A large copy number for the antifreeze protein gene was found in flounder sampled from locations where ice or low temperatures commonly occur (Shinnecock Bay, Bay of Fundy and Newfoundland). In areas where winter temperatures are warmer (Passamaquoddy Bay, Georges Bank, and Browns Bank), the copy number for this gene was reduced. In addition, Browns Bank and Georges Bank flounder had dissimilar copy numbers and tandem components, suggesting that these groups were genetically distinct, despite their close geographic proximity. However, the results of Hayes et al. (1991) should be considered with caution, because only one fish was sampled from each location.

Seasonal Movements and Applied Marks

Tagging studies can provide important insight into the stock structure of marine fish. Movement data obtained from tagging can be used to estimate the geographic ranges of different stocks, the physical and environmental boundaries that restrict movement between groups, and the rates of interchange between individuals in different stock areas. Groups of fish that are discrete in time or space are managed more appropriately as a single unit. However, if multiple groups of fish exhibit overlapping distributions, they are typically managed more appropriately as a single stock.

Mark-recapture studies have provided evidence that winter flounder exhibit spawning site fidelity (Perlmutter, 1947; Saila, 1961; Danila and Kennish, MS 1982; Scarlett and Schneider, MS 1986; Phelan, 1992). For example, Perlmutter (1947) tagged winter flounder from New Jersey to Maine, and divided the tagging area into ten strata for analysis. Ninety four percent of tagged individuals were recaptured within the stratum in which they were tagged, and limited movement was observed during the spawning season. Phelan (1992) also found evidence for fidelity of individuals tagged within the Inner New York Bight, as many individuals were recaptured in close proximity to their release location (i.e., spawning site) after over 100 days at liberty.

The seasonal movement patterns of winter flounder vary between the three U. S. stocks. Seasonal movements in the Gulf of Maine are typically localized and confined to inshore waters (Perlmutter, 1947; McCracken, 1963; Howe and Coates, 1975). Coates et al. (MS 1970) reported that the mean displacement of tagged individuals in the Gulf of Maine was only 5.1km. In the Gulf of Maine, adults are typically found in deeper coastal waters during the winter months, and move inshore to shallow coastal waters in the spring as temperatures increase (Bigelow and Schroeder, 1953; Howe and Coates, 1975; DeCelles and Cadrin, 2010).

Winter flounder in the SNE/MA area undergo more extensive migrations, typically leaving shallow bays and estuaries in the spring and summer months as water temperatures increase above 15^{o}C. Several tagging studies documented a general trend for SNE/MA flounder to disperse to the south and east during the summer months (Perlmutter, 1947; Saila, 1961; Howe and Coates, 1975; Powell, 1989; Phelan, 1992). During these migrations, some flounder in the SNE/MA stock will move short distances to cooler coastal waters, while others have been observed making longer migrations. For example, Powell (1989) observed that some adult flounder tagged in Narragansett Bay dispersed eastward to Nantucket Shoals and the waters south of Marthas Vineyard. During the summer and fall migration, members of the localized inshore groups of winter flounder in the SNE/MA stock intermix in coastal waters, a phenomenon described by Phelan as a “dynamic assemblage”. Based on tag-recapture data the mean displacement of winter flounder tagged in the SNE/MA stock area was 26.5km (Coates et al., MS 1970). Flounder on Georges Bank remain offshore year round (Howe and Coates, 1975), and seasonal movement patterns on Georges Bank are difficult to distinguish (Coates et al., MS 1970). Individuals in the Georges Bank stock are not dependent upon estuaries to complete their life cycle.

Tagging studies have shown that the rate of interchange between the three U. S. stocks is low. Howe and Coates (1975) found that only 1.7% of tagged flounder moved between the Gulf of Maine and the SNE/MA area, and that little interchange (0.49%) exists between the SNE/MA and Georges Bank stocks. These findings suggest that the three management units of winter flounder in U.S. coastal waters are relatively discrete, and that reproductive isolation is likely between these stocks.

Tagging studies provide evidence of contingent structure in the SNE/MA and Gulf of Maine winter flounder stocks. Contingents are cohesive groups of fish within a population that exhibit a common migration pattern (Cadrin and Secor, 2009). Contingent migrations may make a stock more resilient to overfishing, increase genetic diversity and cause variable susceptibility to anthropogenic impacts (Secor, 1999; Hilborn et al. 2003). Contingent structure within winter flounder stocks warrants further research, and contingent structure should be considered in management and designations of Essential Fish Habitat.

In the SNE/MA stock, evidence of contingent structure has been observed using mark-recapture experiments. Historically, two groups of winter flounder were thought to be present off Long Island; a migratory group and a resident (“bay”) group (Lobell, MS 1939; Perlmutter, 1947). Lobell (MS 1939) and Olla (1969) documented the presence of a resident group of flounder that remained in Great South Bay, NY throughout the summer, where temperatures were as high as 24^{o}C. A recent acoustic telemetry experiment (Sagarese, MS 2009) found evidence of a resident group of adult flounder, which remained in Shinnecock Bay during the summer, where temperatures reached 24^{o}C. Scarlett and Schneider (MS 1986) also found evidence for partial migration in winter flounder that were tagged in the Shark and Manasquan Rivers, NJ. In most years, tagged flounder in this region dispersed to deeper coastal waters during the summer months. However, in 1984, few offshore movements were observed, and nearly all flounder were recaptured in close proximity to the tagging sites.

There is some evidence to suggest that contingent groups of flounder may be spawning in coastal waters in the SNE/MA stock area. Phelan (1992) reported that some flounder tagged in the New York Bight were recaptured in coastal waters, rather than estuaries, during the spawning season. Phelan postulated that these individuals likely did not spawn offshore and were either late inshore spawners or possibly did not spawn at all to conserve body mass. More recently, Wuenschel et al. (2009) collected ripe fish off the coast of New Jersey, and suggested that in this region, some flounder may be spawning in coastal waters, rather than estuaries.

Contingent structure has also been recognized in some regions of the Gulf of Maine stock area. Based on tag return data, Howe and Coates (1975) suggested that groups of flounder may be spawning in coastal waters, rather than estuaries. Recently, acoustic telemetry has been used to study the movements and distribution of adult winter flounder. Acoustic telemetry allows the behavior of individual fish to be tracked with high spatial and temporal resolution, and allows for the recognition of contingent behavior (Secor, 1999). Using acoustic telemetry, DeCelles and Cadrin (2010) observed two contingents of winter flounder, which exhibited divergent spawning behavior. One contingent spawned in coastal waters, while another contingent was observed migrating to estuaries during the spawning period.

Fairchild et al. (MS 2010) tagged forty adult winter flounder with acoustic transmitters on the southern portion of Jeffreys Ledge. Acoustic receivers were deployed as gates across the mouths of six estuaries from Portsmouth, NH southward to the Annisquam River, MA. She found that the majority of tagged winter flounder remained in coastal waters during the spawning season, while a small number migrated to estuaries to spawn.

McCracken (1963) observed seasonal distributions of winter flounder in several regions of Canada. In St. Marys Bay and Passamaquoddy Bay, New Brunswick (NAFO Div. 4X) winter flounder dispersed to deeper water during the winter months, and gradually moved inshore to shallow water to spawn during the spring. During the summer months, some large fish dispersed to deeper waters in the bays, while other remained in the shallows. In Pubnico Harbor, Nova Scotia, McCracken (1963) found that flounders began to return to the shallow waters of the bay in April. During the summer months, adult flounder left the bay, and moved to coastal waters where water temperatures were cooler.

In the Gulf of St. Lawrence, winter flounder exhibit a patchy distribution. Trawl surveys have found this species to be abundant east and west of the Magdalen Islands, east of Prince Edward Island, in Northumberland Strait, in the Miramichi estuary, and Chaleur Bay (Morin et al., MS 2002). Based on tag return data, the seasonal movements of adult flounder in the Gulf of St. Lawrence appear to be limited (DFO, MS 2005). McCracken (1963) observed that in Northumberland Strait, mature flounder will overwinter in cool deep waters, move to shallow inshore areas in the spring, and return to deeper waters (15-24m) during the summer months. Trawl survey data shows that flounder appear to overwinter in deeper waters 10-20 km offshore of the Magdalen Islands (Hanson and Courtenay, 1996). In contrast, winter flounder appear to overwinter in the shallow waters of the Miramichi estuary in the southern Gulf of St. Lawrence (Hanson and Courtenay, 1996). Hanson and Courtenay (1996) reported that flounder began to enter the Miramichi estuary in late autumn, and overwintered in this habitat, where water temperatures were warmer than the Southern Gulf, and where a refuge existed from flowing ice packs. In spring as the salinity of the estuary was reduced by snow melt, adult fish left the estuary and migrated to spawning grounds in coastal waters.

Winter flounder appear to be common in near shore waters (<60 m) along the coast of Newfoundland and Labrador (Kulka and DeBlois, MS 1996), although its distribution in shallow water is not well sampled by commercial catches and trawl surveys. Kennedy and Steele (1971) observed that winter flounder in Long Pond, Conception Bay, Newfoundland exhibited seasonal distribution patterns that were similar those undertaken by winter flounder in the SNE/MA stock. Individuals remained inshore in shallow waters from September until June. After spawning in May and June adults migrated offshore to deeper waters to feed. Similar movement patterns were also observed by Van Guelpen and Davis (1979) in Conception Bay, where storm-induced turbulence or the formation of ice in shallow waters caused winter flounder to temporarily emigrate to deeper inshore waters. Results from a small-scale tagging study conducted by Van Guelpen and Davis (1979) indicated that flounder display a high degree of residence in Conception Bay.

In summary, tagging information suggests that limited mixing occurs between the current management areas. Seasonal movement patterns also vary by geographic region. South of Cape Cod, it appears that winter flounder mix in coastal waters in summer, but exhibit fidelity to estuarine spawning grounds in winter and spring. In more northern habitats, residence in estuarine habitats is variable, with some groups spawning on offshore banks, others wintering in estuaries, and others occupying estuaries briefly. Contingent structure appears to exist, because this species has been shown to exhibit divergent spawning behaviors and partial migration. These differences in spawning behaviors may have important implications for reproductive mixing or isolation among spawning groups.

Synthesis and Conclusion

<u>Basis for Assignment of Management Stock Units in the United States and Canada</u>

Prior to 1996, winter flounder were managed as four stock units in the U.S. waters of the northwest Atlantic: Mid-Atlantic, Southern New England, Georges Bank and Gulf of Maine. In 1996 (at the 21st Stock Assessment Workshop, SAW), the Southern New England and Mid- Atlantic groups were combined to form a single unit for assessment purposes (Shepherd et al., MS 1996). The decision to combine these stocks was primarily based on tagging data (Perlmutter, 1947; Howe and Coates, 1975; Phelan, 1992), which indicated that mixing of individuals occurred between these two stock areas. Life history traits (growth rate and length structure) were also observed to be similar between the two units.

The stock structure of Gulf of Maine winter flounder was also reviewed at the 21st SAW. The review concluded that sufficient interchange exists between populations of winter flounder in the Gulf of Maine to manage them as a single stock unit (Cadrin et al., MS 1996). The 28th SAW examined the stock structure of Georges Bank winter flounder and determined that based on (a) tagging data (Howe and Coates, 1975), (b) meristic analysis (Lux, 1973) and (c) differences in life history characteristics (Lux et al., 1970) that the winter flounder on Georges Bank should be managed as a separate stock.

The geographic distribution of winter flounder observed during Canadian summer research vessel surveys on the Scotian Shelf (Stobo et al., MS 1997; DFO, MS 1997) and in the Southern Gulf of St Lawrence (Morin et al., MS 2002; MS DFO 2005) provides the basis for the management units of flounder in Canadian waters. Winter flounder came under TAC management on the eastern (NAFO Div. 4VW) and western (NAFO Div. 4X) Scotian Shelf in 1994. Due to the lack of reliable landings statistics, yellowtail flounder, witch flounder, winter flounder and American plaice are managed concurrently under a single TAC on the Scotian Shelf (DFO, MS 2002b).

Winter flounder have been managed under a TAC in the southern Gulf of St. Lawrence (NAFO Div. 4T) since 1996, although the first assessment of this stock was conducted in 1994 (DFO, MS 2005). Several localized stock units (or partially isolated breeding populations) are thought to exist in the region based on geographic differences in resource survey abundance trends, but information to assess local stock units is limited (Morin et al., MS 2002). A sentinel trawl survey was initiated in 2003 to monitor the distribution and abundance of winter flounder in nearshore areas of the Gulf of St. Lawrence (DFO, MS 2005). Winter flounder are distributed in the coastal waters of Newfoundland (NAFO Div. 3), but are not managed under a TAC system due to continued data limitations (DFO, MS 1996).

Critique of Assigned Stock Units

The management of winter flounder fisheries in U.S. waters is generally consistent with the multidisciplinary information that is available on stock structure. In Canadian waters, stock structure may exist at finer spatial scales than are currently considered in management. Questions regarding the stock structure of this species in both U.S. and Canadian waters persist, despite past research. As stock identification techniques continue to develop and mature, new information may become available to manage and assess this species at finer spatial scales. The most useful information for managers will incorporate a holistic approach, with the goal of achieving congruent results from multiple disciplines (Begg and Waldman, 1999).

Several lines of evidence imply that winter flounder are appropriately managed as separate stock complexes in the SNE/MA and Gulf of Maine. Tagging studies (i.e., Perlmutter, 1947, and Howe and Coates, 1975) showed that patterns of seasonal migration vary dramatically between the two stocks. SNE/MA winter flounder exhibit faster growth than the Gulf of Maine stock (Figures 4 and 5), and spawn earlier in the year (Table 3). Additionally, meristic characters indicate that the flounder resources in these areas comprise disparate stocks (Perlmutter, 1947; Lux et al., 1970; Pierce and Howe, 1977).

While it is likely that localized population structure exists in the SNE/MA stock, it would be practically impossible to identify and manage each of these units as a discrete entity. In this region, most commercial fishing effort occurs when adult fish from each localized stock are mixed in coastal offshore waters. In stock composition analysis, individuals harvested in a fishery are examined to estimate the relative contribution of each stock to the biomass that is available for harvest in an area (Prager and Schertzer, 2005). Multiple approaches can be used for stock composition analysis (i.e., meristics, genetics and parasite characteristics), based on the differences that exist between disparate stocks. Stock composition analysis in the SNE/MA area would help to address questions regarding the relative contribution of each local population to the fishery harvest. In particular, stock composition analysis is needed in the Great South Channel and Nantucket Shoals. This region supported a historical trawl fishery that targeted cod and winter flounder during the summer and fall. Winter flounder are known to spawn on Nantucket Shoals (Pereira et al., MS 1999), and flounder tagged in this region appeared to remain on Nantucket Shoals and the Great South Channel throughout the year (Coates et al., MS 1970). Some winter flounder have been observed migrating from inshore areas to the Great South Channel and Nantucket Shoals during the summer months (i.e., Powell, MS 1989). Therefore, it is possible that flounder harvested in this region may represent a mixture of migrants from inshore populations in the SNE/MA area, as well as a resident component of flounder that spawn on Nantucket Shoals and the Great South Channel.

The Georges Bank stock should be managed as a single transboundary resource in the U.S. and Canadian waters of Georges Bank. Winter flounder in this area exhibit the highest growth rates (Figures 3 and 4) and the largest sizes (Table 1) throughout the range of the species. Fin ray counts (i.e., Lux et al., 1970) suggest that winter flounder on Georges Bank are discrete from other areas. Additionally, Georges Bank flounder exhibit little interchange with inshore stocks. Genetic studies examining gene expression (Hayes et al., 1991) and microsatellite markers (McClelland et al., 2005) suggest that Georges Bank flounder are distinct from those found on the western Scotian Shelf. Flounder on Georges Bank and the western Scotian Shelf also exhibit disparate parasite characteristics (McClelland et al., 2005).

Gulf of Maine winter flounder are the least studied of those in U.S. waters. Historical tagging data (Perlmutter, 1947; Howe and Coates, 1975) indicate that seasonal movements are limited, and that several local stocks may be present in the Gulf of Maine. New mark-recapture experiments would be help to investigate population structure in the Gulf of Maine. Tagging pre-spawning and spawning flounder throughout the Gulf of Maine would be an effective way to examine mixing rates between individuals in local spawning populations. Genetic analysis of spawning flounder using microsatellite markers would also be useful to reveal the degree of local stock structure that exists in the Gulf of Maine. At present, there is no research that distinguishes Gulf of Maine winter flounder from those found in inshore Canadian waters of the Bay of Fundy or the Scotian Shelf. In addition to tagging studies, data from trawl surveys may also be examined to detect any persistent differences in life history traits between inshore flounder populations in the northern Gulf of Maine and southern New Brunswick. Winter flounder in these regions may also be connected through larval dispersal. Coupled biophysical individual based models would be useful for examining the possibility of larval transport between the Gulf of Maine and the Scotian Shelf (e.g., DeCelles et al., MS 2010).

Contingent structure within flounder stocks warrants further investigation. Acoustic telemetry has shown promise in identifying contingent spawning and migratory behavior for this species (Sagarese, MS 2009; DeCelles and Cadrin, 2010; Fairchild et al., MS 2010). Coast-wide receiver arrays, which were proposed by Grotheus and Able (2007), would be a useful tool for examining the prevalence of costal spawning winter flounder groups. Evidence for coastal spawning could also be gathered using benthic ichthyoplankton surveys. Since winter flounder spawn adhesive and demersal eggs (Klein-MacPhee, 1978), spawning locations can be inferred from areas where eggs are sampled. Directed trawl surveys during the spawning season would also offer insight into the relative importance of coastal spawning in winter flounder stocks.

Management units of Canadian winter flounder are assigned on the basis of abundance patterns derived from resource surveys. These stock boundaries could be refined using a variety of complimentary stock identification techniques. Life history traits (such as growth and maturity), which are sampled during research surveys could be used to improve the resolution of stock boundaries. Other disciplines, such as genetics and meristics may also prove useful in the investigation of Canadian stock structure for this species.

Currently, all winter flounder in NAFO Div. 4X are managed under a single TAC encompassing four different flounder species (witch, yellowtail, plaice and winter flounder). However, evidence suggests that at least two stocks of winter flounder exist within the western Scotian Shelf (NAFO Div. 4X). McClelland et al. (2005) found that winter flounder on Browns Bank are distinct from those inhabiting St. Marys Bay based on microsatellite analysis and parasitic characteristics. In addition, Hayes et al. (1991) noted differences in the expression and copy number of antifreeze protein genes between Browns Bank winter flounder and those in the inshore areas of the Bay of Fundy. Additionally, data from the spring survey in the Scotian shelf has found evidence for a stock of winter flounder that spawn offshore on Browns Bank (Neilson and Hurley, MS 1986). A mark-recapture study could be used to look for movement between flounder on Browns Bank and inshore areas of the Scotian shelf. If limited interchange exists between these two regions, they may be managed more appropriately as separate stocks.

On the eastern Scotian Shelf (NAFO Div. 4VW), the distribution of winter flounder is restricted to Sable Island Bank. Analysis of parasitic characters and microsatellite markers suggest that flounder on the eastern Scotian Shelf are distinct from other Canadian stocks (Scott, 1982; McClelland et al., 2005). Based on the available literature, winter flounder in the 4VW region appear to be managed appropriately as a single stock.

Winter flounder in the southern Gulf of St. Lawrence stock (NAFO Div. 4T) are geographically isolated from other stock units, and analysis of microsatellite markers and parasite characteristics suggests the flounder in the Gulf of St. Lawrence are distinct from other stocks (McClelland et al., 2005). While multiple stocks of winter flounder are likely present in the southern Gulf of St. Lawrence, the resource is managed as a single stock due to data limitations (Morin et al., MS 2002). Winter flounder exhibit a patchy distribution throughout the region, indicating that several stocks may be present (Morin et al., MS 2002). Seasonal movements appear to differ between winter flounder in different regions in the Southern Gulf of St. Lawrence. For example, flounder in some regions (Miramichi estuary) overwinter in estuaries, while in other areas (Magdalen Islands) they occur in offshore waters during the winter (Hanson and Courtenay, 1996). Growth rates (Figure 6) vary substantially between flounder in the southern (Northumberland Strait) and northern (St. Lawrence estuary) Gulf of St. Lawrence, and common garden experiments suggest the slow growth exhibited by flounder in the St. Lawrence estuary may have a genetic basis (Fraboulet et al., 2009).

There are several methods available to investigate the fine-scale stock structure of winter flounder in the Gulf of St. Lawrence. Conventional tagging experiments could be used to determine whether interchange occurs between the local populations that are present in the Gulf of St. Lawrence. Information gathered from the sentinel trawl survey could also be used to look for persistent differences in life history traits between flounder from different regions of the 4T stock. Finally, microsatellite markets could be used to investigate fine-scale stock structure in the Gulf of St. Lawrence.

Interdisciplinary stock identification analyses provide researchers, managers, and assessment scientists with a more holistic perspective on the spatial structure of marine fish populations. Incorporating results from multiple disciplines increases the probability that stock boundaries will be assigned accurately (Hohn, MS 1997). Further, in many instances, disparate approaches (i.e., genetic and phenotypic) will yield complimentary information (Coyle, 1998).

More recent studies using advanced technology, such as acoustic telemetry, have revealed the presence of complex spatial structure in populations of winter flounder. Accounting for this spatial structure in fisheries management and stock assessment is challenging, and will require new analytical approaches (i.e., Cadrin and Secor, 2009). To manage winter flounder stocks with greater spatial resolution, concurrent advances in stock identification and stock assessment methodologies will be needed.

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List of Tables and Figures

Table 1.

Stock Area	Region	Sex	K	$L_{inf\ (cm)}$	t_0	Source
SNE/MA	Narragansett Bay, RI	Male	0.27	39.0	-0.23	Berry et al. (1965)
	Narragansett Bay, RI	Female	0.29	45.1	0.07	Berry et al. (1965)
	South of Cape Cod	Male	0.25	47.7	-	Howe and Coates (1975)
	South of Cape Cod	Female	0.34	48.8	-	Howe and Coates (1975)
	South of Cape Cod	Male	0.31	45.9	0.16	Witherell and Burnett (1993)
	South of Cape Cod	Female	0.31	49.0	0.25	Witherell and Burnett (1993)
Georges Bank	Eastern Georges Bank	Male	0.37	55.0	-0.05	Lux (1973)
	Eastern Georges Bank	Female	0.31	63.0	0.05	Lux (1973)
	Georges Bank	Male	0.37	53.4	-	Howe and Coates (1975)
	Georges Bank	Female	0.45	62.2	-	Howe and Coates (1975)
Gulf of Maine	North of Cape Cod	Female	0.37	45.5	-	Howe and Coates (1975)
	North of Cape Cod	Male	0.41	39.8	0.38	Witherell and Burnett (1993)
	North of Cape Cod	Female	0.27	49.0	0.07	Witherell and Burnett (1993)
4X	St. Marys Bay	Combined	0.34	43.9	0.35	McCracken (MS 1954)
	Scotian Shelf	Male	0.45	39.7	0.41	Neilson and Hurley (MS 1986)
	Scotian Shelf	Female	0.30	46.3	0.92	Neilson and Hurley (MS 1986)
4T	Northumberland Strait	Combined	0.25	40.2	0.38	McCracken (MS 1954)
	St. Lawrence Estuary	Combined	0.22	37.6	0.73	Vaillancourt et al. (1985)

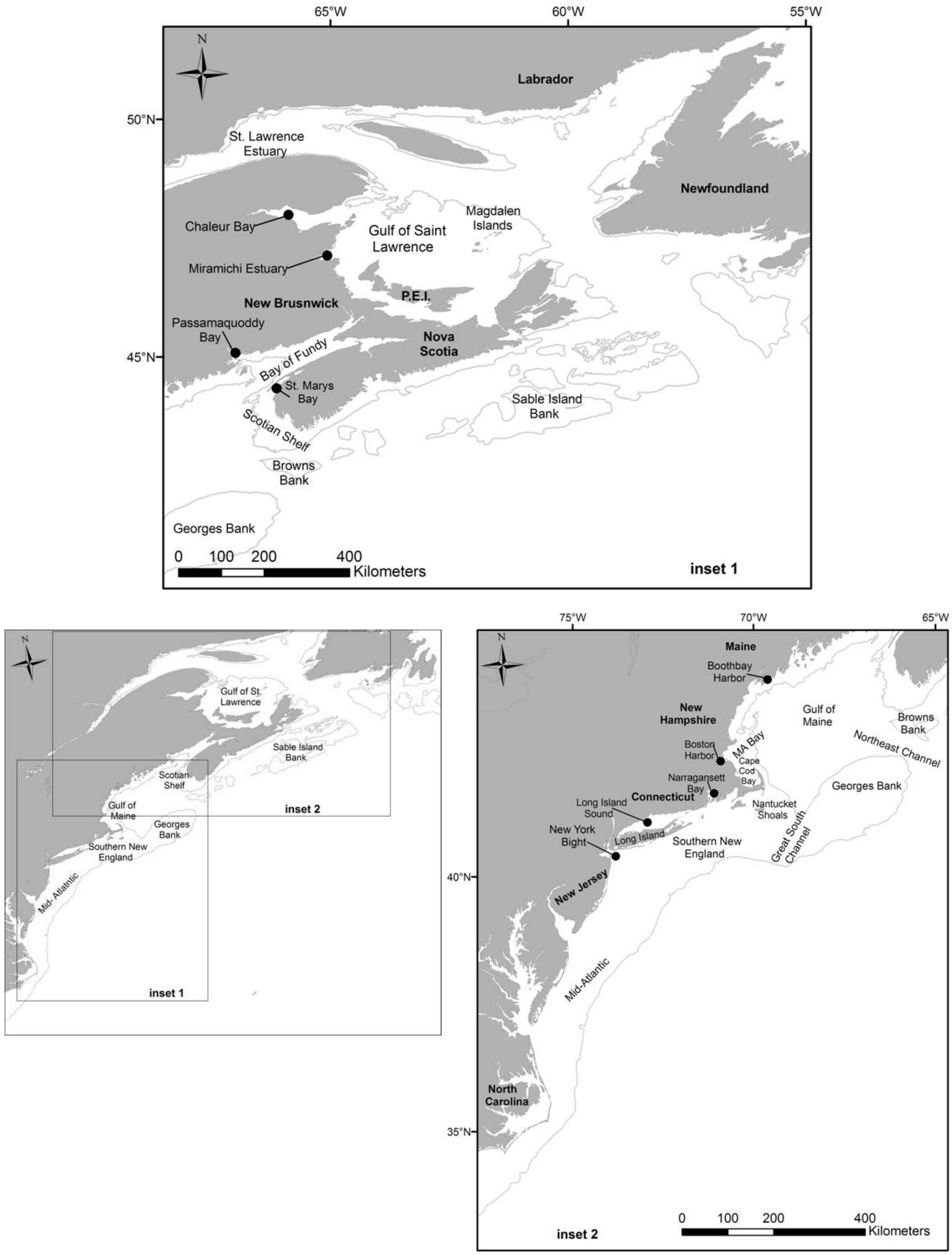
Table 2.

Stock	A50 Males (y)	A50 Females (y)	L50 Males (cm)	L50 Females (cm)	Citation
SNE/MA	2.0	3.0	20-25	20-25	Perlmutter, 1947
	3.3	3.0	29.0	27.6	O'Brien et al., MS 1993
	3.1	3.0	28.0	28.3	Witherell and Burnett, 1993
Georges Bank	1.9	1.9	25.6	24.9	O'Brien et al., MS 1993
Gulf of Maine	3.3	3.5	27.6	29.7	O'Brien et al., MS 1993
	3.3	3.3	27.2	28.7	Witherell and Burnett, 1993
Gulf of St. Lawrence	-	-	21	24	DFO, MS 2010
Newfoundland	6.0	7.0	21.0	25.0	Kennedy and Steele, 1971

Table 3.

Stock	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Citation
SNE/MA			****	****	XXXX	****			Pearcy, 1962
	****	****	****	****	****				Fairbanks et al., MS 1971
			****	****	XXXX				Buckley et al., 1991
					****	****			Monteleone, 1992
			****	XXXX	XXXX	****	****		Collette and Klein-MacPhee, 2002
Georges Bank						****	****		Kendall, 1912
						****	****		Bigelow and Schroeder, 1953
					****	****	****		Reid et al., MS 1999
Gulf of Maine					****	XXXX	****		Bigelow and Schroeder, 1953
					****	****			Lux and Kelly, MS 1982
						****	****		Normandeau Associates, MS 2009
					****	XXXX	****		Fairchild et al., MS 2010
Passamaquoddy Bay							****		McCracken, 1963
							****		Fraboulet et al., 2009
St. Lawrence Estuary								****	Fraboulet et al., 2009
Newfoundland					****	****	XXXX	XXXX	Kennedy and Steele, 1971
								****	Van Guelpen and Davis, 1979

Figure 1.


65°W
60°W
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50°N
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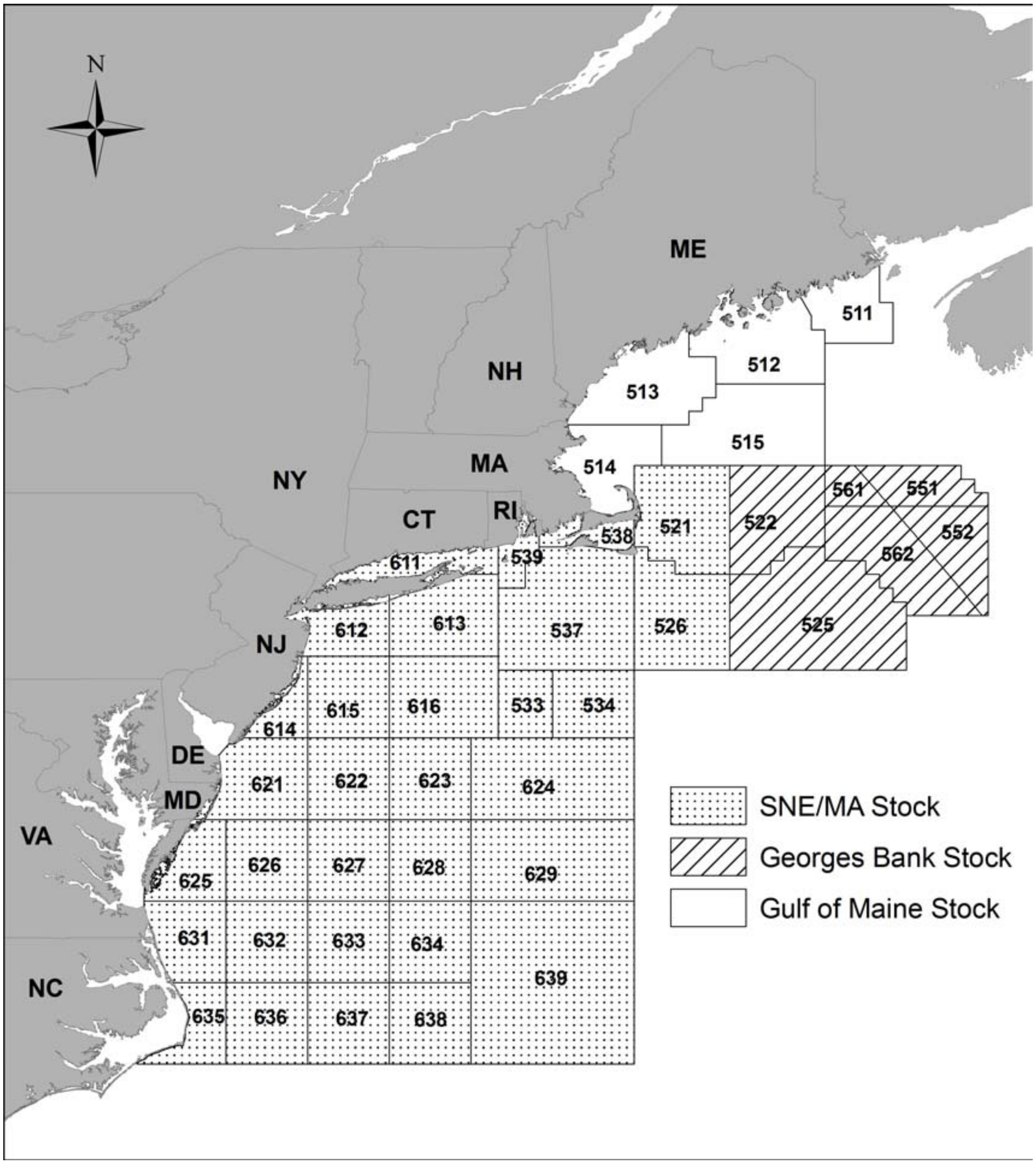
Newfoundland
Chaleur Bay
Magdalen Islands
Gulf of Saint Lawrence
Miramichi Estuary
New Brusnwick
P.E.I.
Passamaquoddy Bay
Nova Scotia
45°N
Bay of Fundy
St. Marys Bay
Sable Island Bank
Scotian Shelf
Browns Bank
Georges Bank
0 100 200 400
Kilometers
inset 1
Gulf of St. Lawrence
Sable Island Bank
Scotian Shelf
Gulf of Maine
Georges Bank
Southern New England
Mid-Atlatnic
inset 2
inset 1
75°W
70°W
65°W
Maine
Boothbay Harbor
New Hampshire
Gulf of Maine
Browns Bank
Boston Harbor
MA Bay
Cape Cod Bay
Northeast Channel
Narragansett Bay
Connecticut
Georges Bank
Long Island Sound
Nantucket Shoals
New York Bight
Long Island
Southern New England
Great South Channel
40°N
New Jersey
Mid-Atlantic
North Carolina
35°N
inset 2
0 100 200 400
Kilometers

Figure 2.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SNE/MA Stock
Georges Bank Stock
Gulf of Maine Stock

Figure 3.

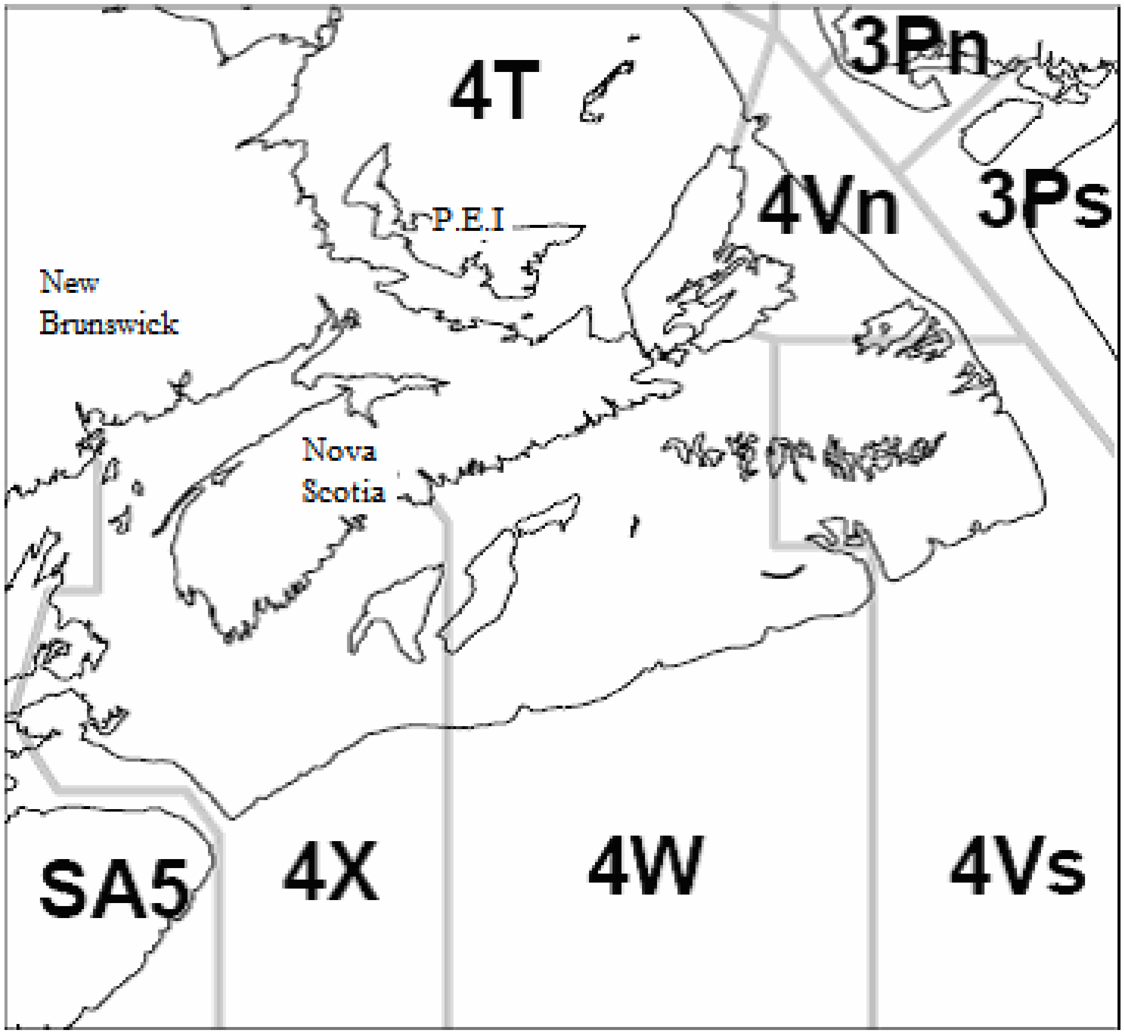
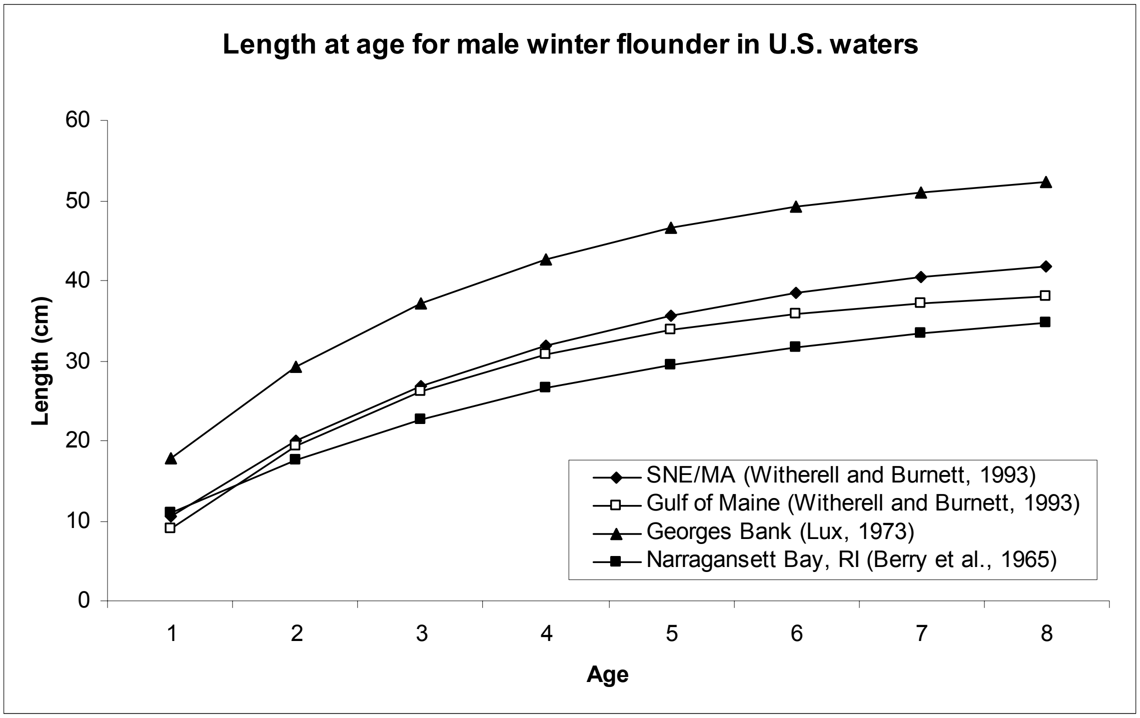
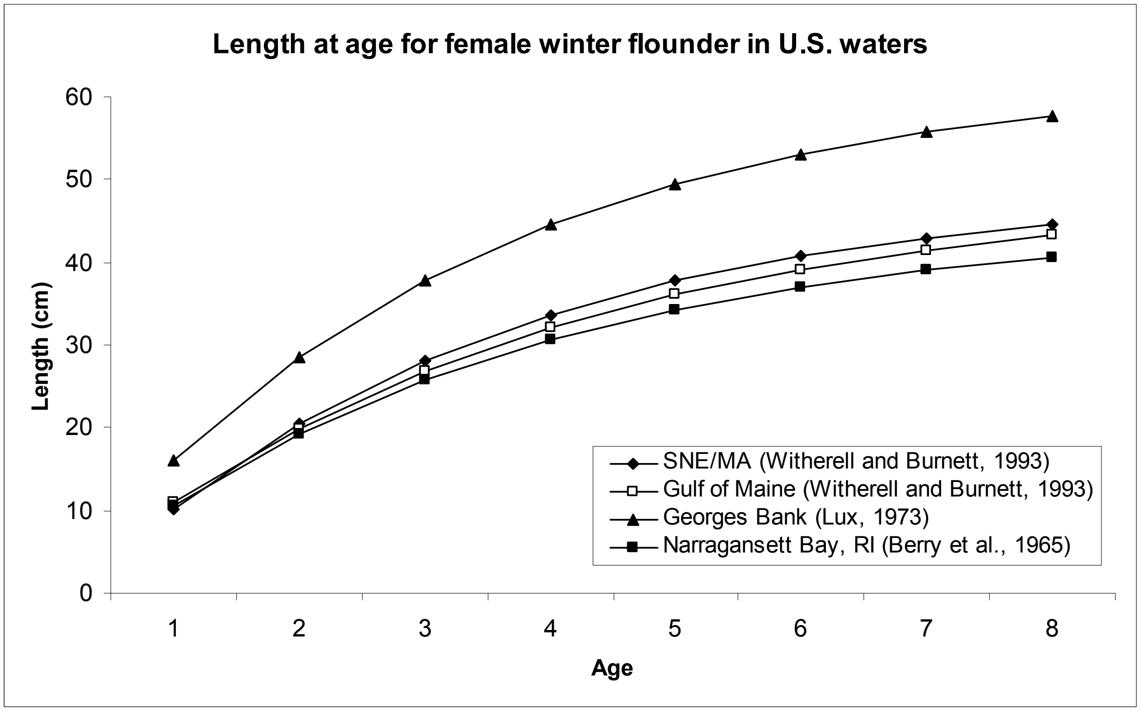


Figure 4.



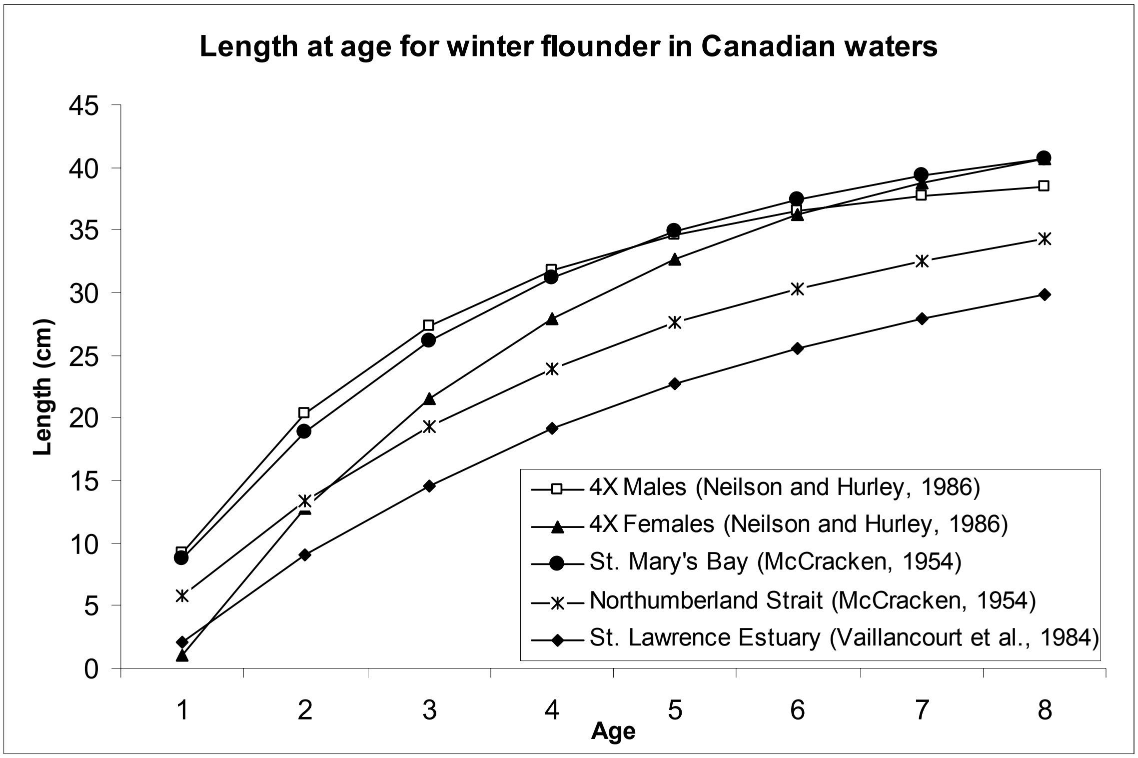
Length at age for male winter flounder in U.S. waters
Length (cm)
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
Age
SNE/MA (Witherell and Burnett, 1993)
Gulf of Maine (Witherell and Burnett, 1993)
Georges Bank (Lux, 1973)
Narragansett Bay, RI (Berry et al., 1965)

Figure 5.



Length at age for female winter flounder in U.S. waters
60
50
40
30
20
10
0
Length (cm)
1
2
3
4
5
6
7
8
Age
SNE/MA (Witherell and Burnett, 1993)
Gulf of Maine (Witherell and Burnett, 1993)
Georges Bank (Lux, 1973)
Narragansett Bay, RI (Berry et al., 1965)

Figure 6.


Length at age for winter flounder in Canadian waters
Length (cm)
45
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
Age
4X Males (Neilson and Hurley, 1986)
4X Females (Neilson and Hurley, 1986)
St. Mary's Bay (McCracken, 1954)
Northumberland Strait (McCracken, 1954)
St. Lawrence Estuary (Vaillancourt et al., 1984)

Impacts of reduced inshore strata sampling

on NEFSC trawl survey indices for SNE/MA winter flounder

Introduction

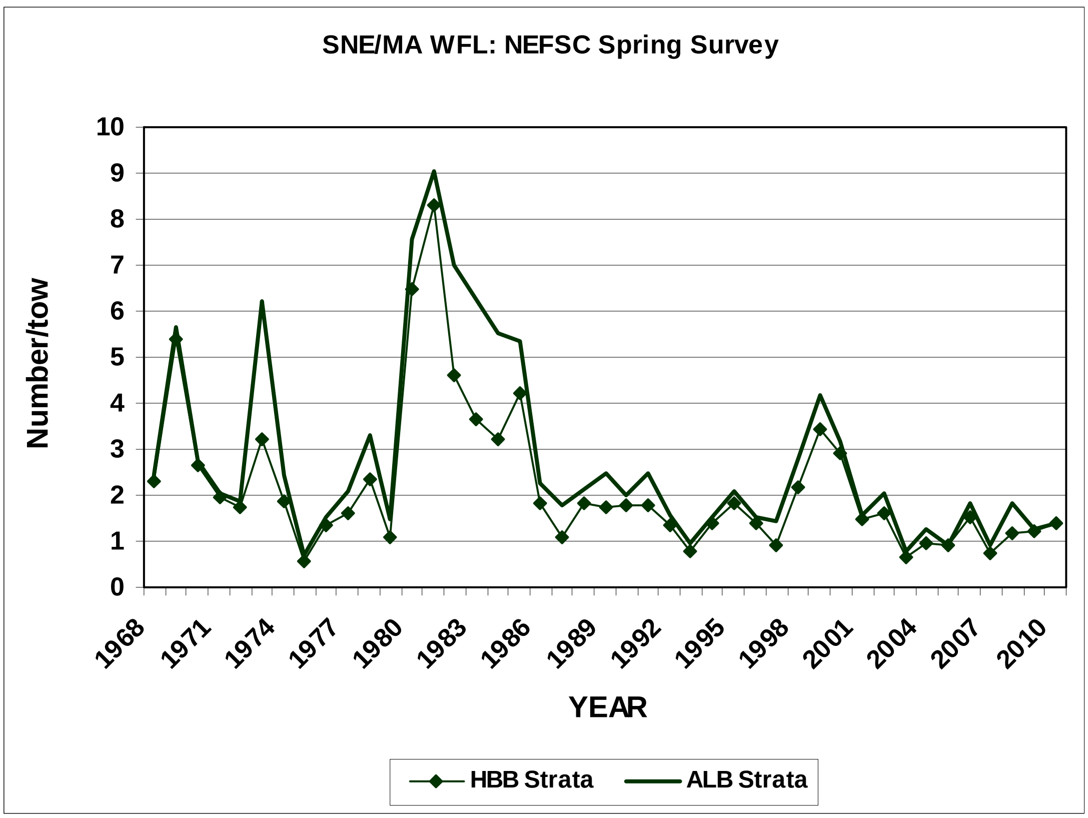
Important changes in the NEFSC bottom trawl survey that were implemented beginning with the 2009 spring survey have significant implications for the use of these data in stock assessments. Prior to 2009, multispecies bottom trawl surveys were conducted primarily on the NOAA FSV *Albatross IV* and infrequently on the NOAA FSV *Delaware II*. The 2009 and 2010 surveys were conducted using the NOAA FSV *Henry B. Bigelow*. The bottom trawl fishing gear used for sampling has also been changed. Prior to 2009, the survey was conducted with a Yankee 36 bottom trawl and 450-kg polyvalent trawl doors. Beginning in 2009, the survey now uses a 400 x 12, 4-seam bottom trawl with 550-kg PolyIce oval trawl doors. The survey towing speed was also changed, decreasing from 3.8 knots prior to 2009 to 3.0 knots beginning in 2009. The new towing speed was selected after extensive scope and tow speed trials conducted on both the FSV *Delaware II* and the FSV *Henry B. Bigelow* and consideration of the range of species to be sampled. The tow duration has also changed from 30 minutes (timed from when the winches were locked until they were reengaged) to 20 minutes of actual bottom time (as determined by net monitoring systems). The adjustments to both tow speed and tow duration have resulted in a decrease of average tow distance from 1.9 nautical miles prior to 2009 to an average tow distance of 1.0 nautical miles beginning in 2009 (Brown 2009).

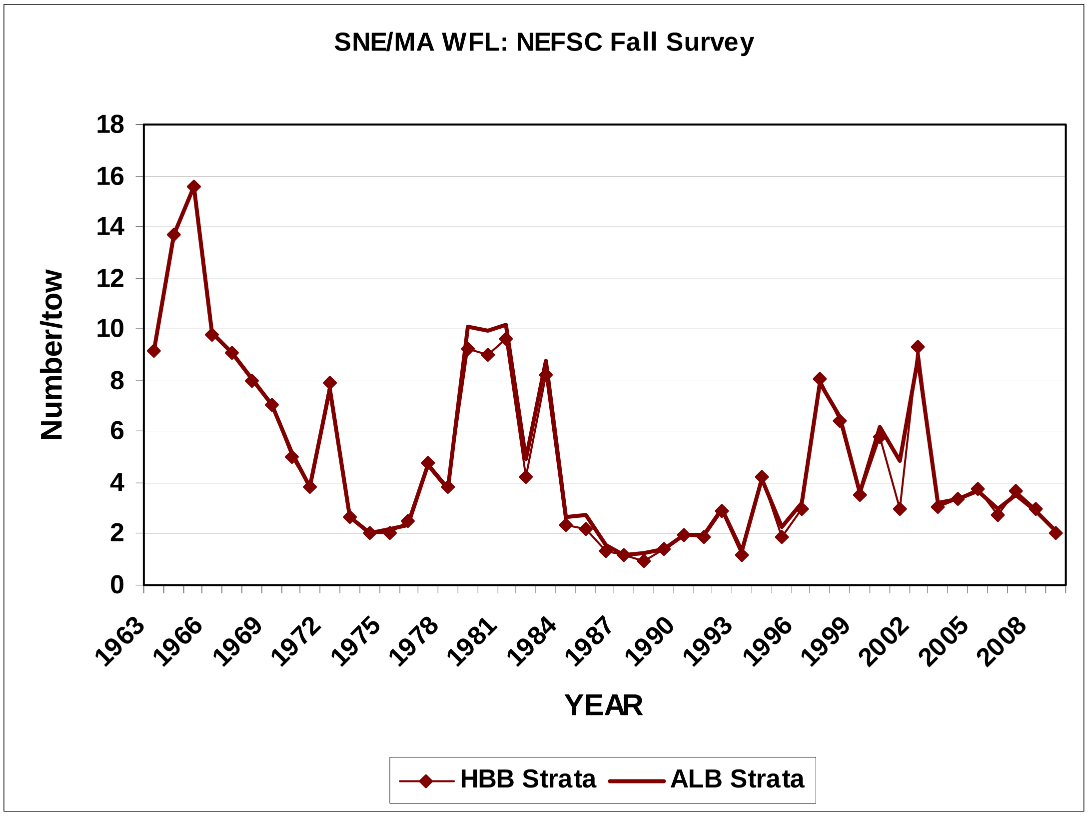
Station allocation also changed significantly due to an increase in total available vessel time from 48 to 60 sea days and a reduction in inshore sampling by the FSV *Henry B. Bigelow*. At the time that inshore strata in the mid-Atlantic were historically sampled (March), survey results indicate low densities of commercially and recreationally important species. These areas will continue to be sampled by the Northeast Area Monitoring and Assessment Program (NEAMAP) bottom trawl survey, although later in the year (late April – early May). As a result of station reallocation, station density was increased significantly in offshore strata that have historically demonstrated higher densities of fish particularly in the mid-Atlantic and southern New England regions (Brown 2009).

The change in station allocation impacts the strata set used in the SNE/MA winter flounder assessment, which has included inshore strata 1-29 and 45-56, in depths from about 10 to 27 meters (5 to 15 fathoms) from Outer Cape Cod to coastal Maryland, as well as offshore strata 1-12, 25, and 61-76. In 2009-2010 (and in the future), the FSV *Henry B. Bigelow* sampled only the deepest inshore strata, from 18 to 27 meters (10 to 15 fathoms). Inshore strata were first included in the SNE/MA winter flounder NEFSC spring indices beginning in 1973, when strata 1-29 and 45 were sampled. Throughout the time series, several inshore strata occasionally have not been not sampled, most often the shallowest strata on Nantucket Shoals (52), in Nantucket Sound (53, 54), east of Cape Cod (56), in Buzzards Bay (45, 51), in Rhode Island Sound (47), along Long Island, NY (3, 12), along coastal New Jersey (18, 21) and coastal Delaware (24, 27).

HBB vs. ALB strata set indices

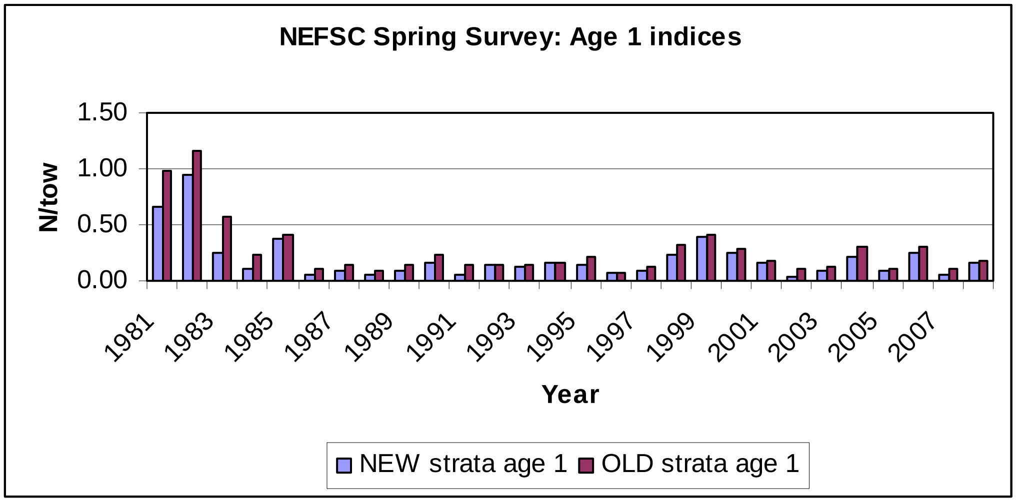
To examine the impact of the revised station allocation on the NEFSC spring and fall survey indices used for model calibration in the assessment (i.e., the 2008 GARM 3 1981-2007/2008 assessment ADAPT VPA model), indices from a new survey strata set including only the deepest inshore strata (HBB strata) were compared with those currently used (ALB strata) for 1981-2008. The following figures indicate that the differences in general are largest for the spring series and the absolute differences area largest during 1982-1985, when the HBB strata set indices average 35% lower than the ALB strata set indices (3.90 fish/tow compared to 6.03 fish/tow). Patterns in biomass indices (kg/tow) are very similar to those in the numeric indices. The strata that consistently account for the differences are inshore strata 1, 4, 7, 9 and 10 along Long Island; inshore strata 12 and 13 off Raritan Bay, NY; inshore strata 18, 19, 21, and 24 off southern New Jersey; inshore stratum 45 off Rhode Island; and inshore stratum 55 on Nantucket Shoals.

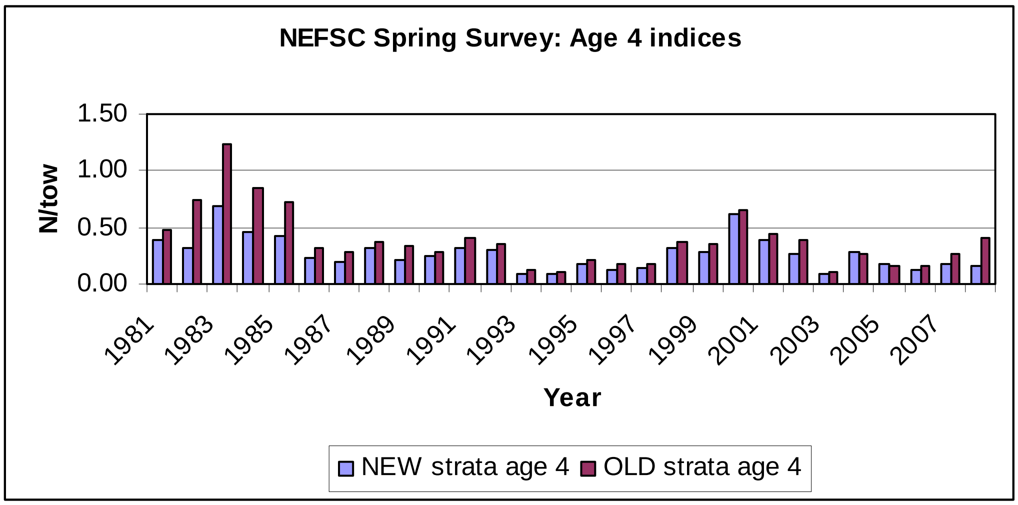


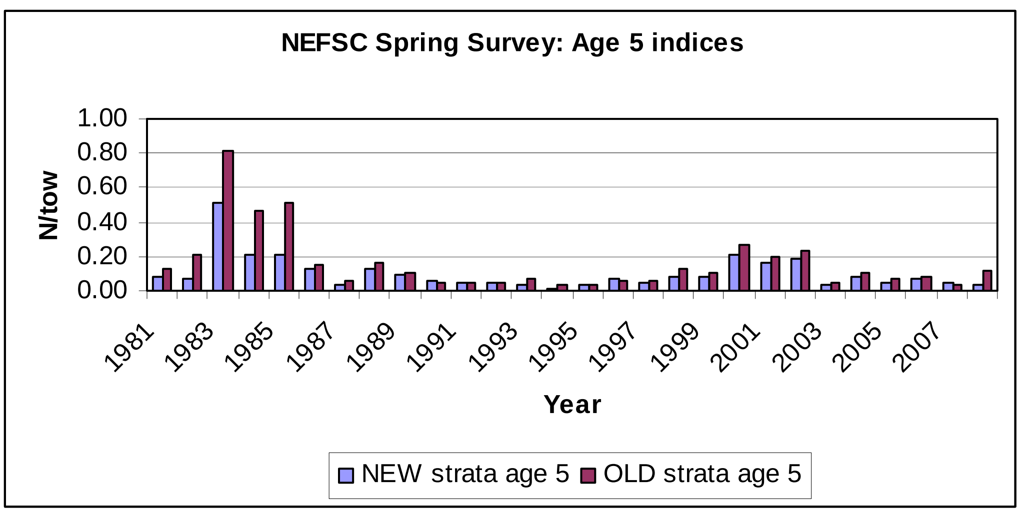


SNE/MA WFL: NEFSC Fall Survey
Number/tow
18
16
14
12
10
8
6
4
2
0
1963
1966
1969
1972
1975
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
YEAR
HBB Strata
ALB Strata

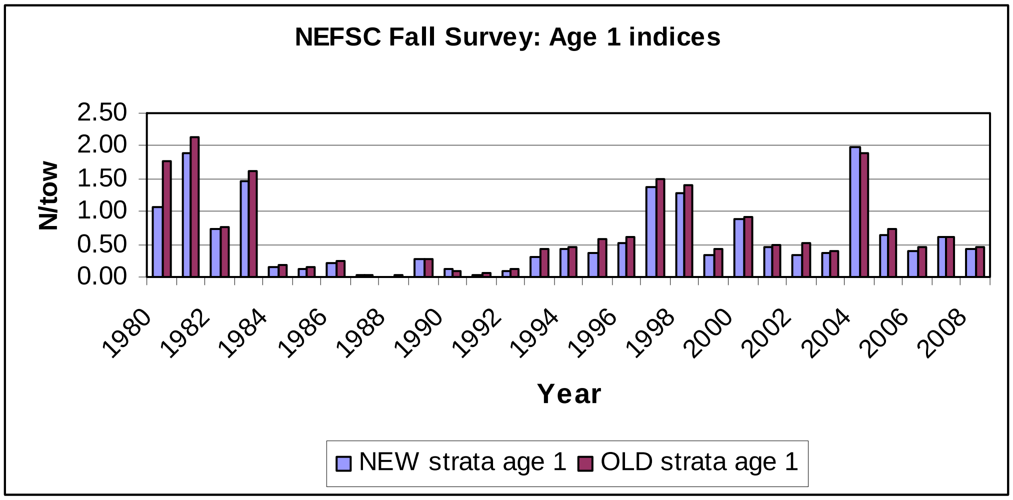
For the indices at age, the differences are largest for the Spring indices at ages 1, 4, and 5, at about a 25% average decrease over the time series, with the largest absolute differences generally for the early to mid 1980s.

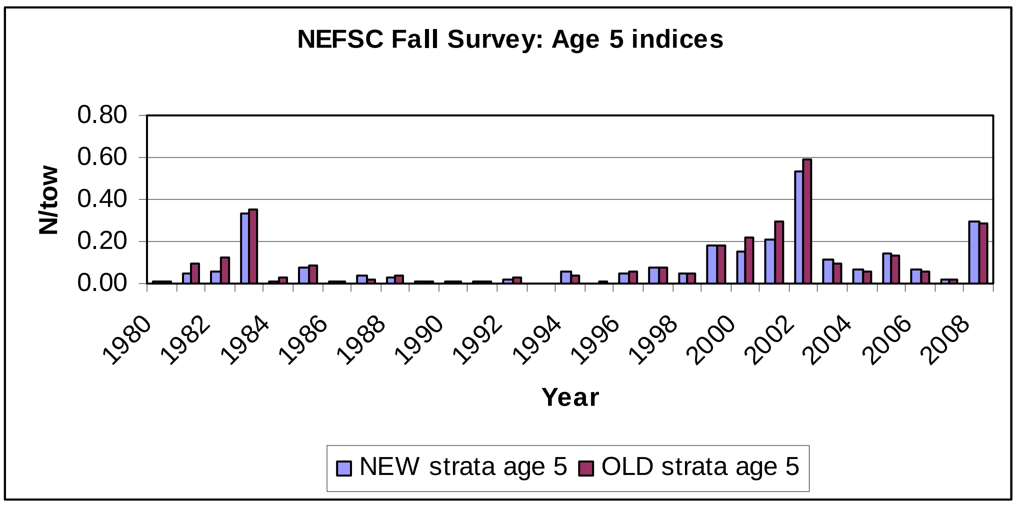






The Fall survey differences are largest for ages 1, and 5, at 14% and 11% average decrease over the time series, with the largest absolute differences generally for the early to mid 1980s and early 2000s.

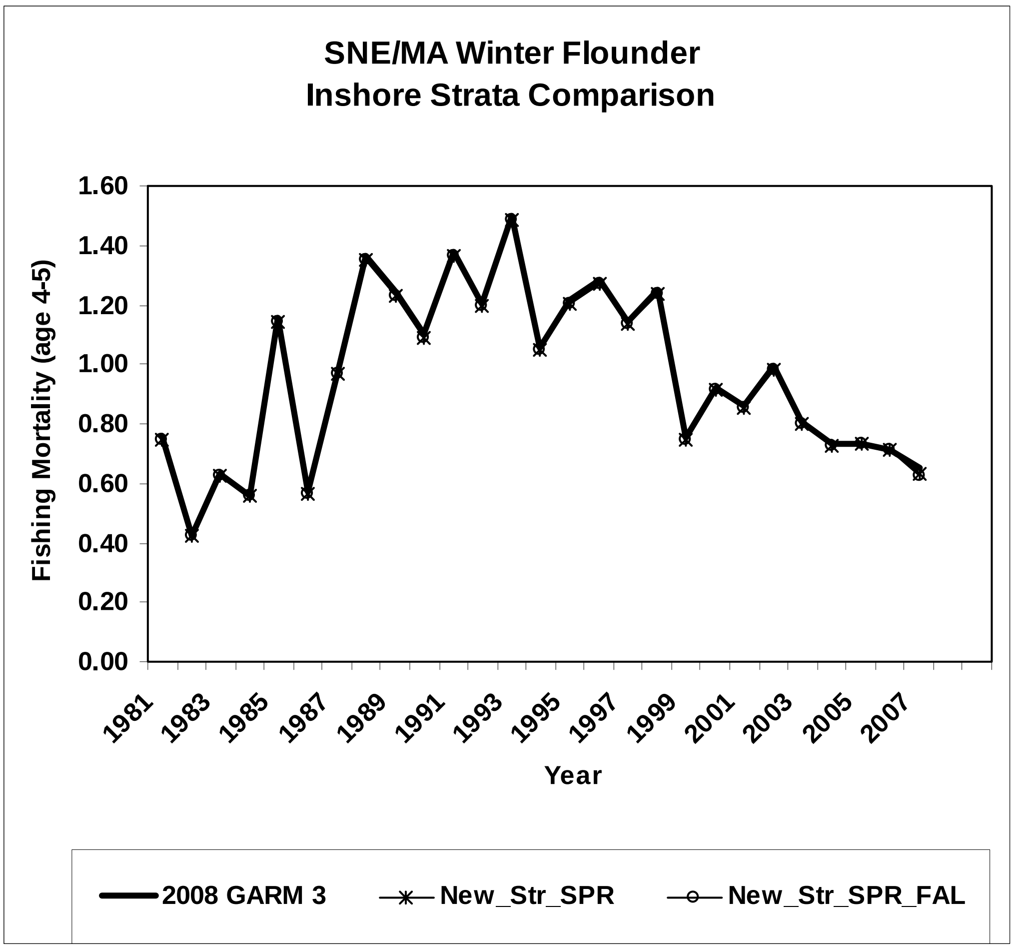




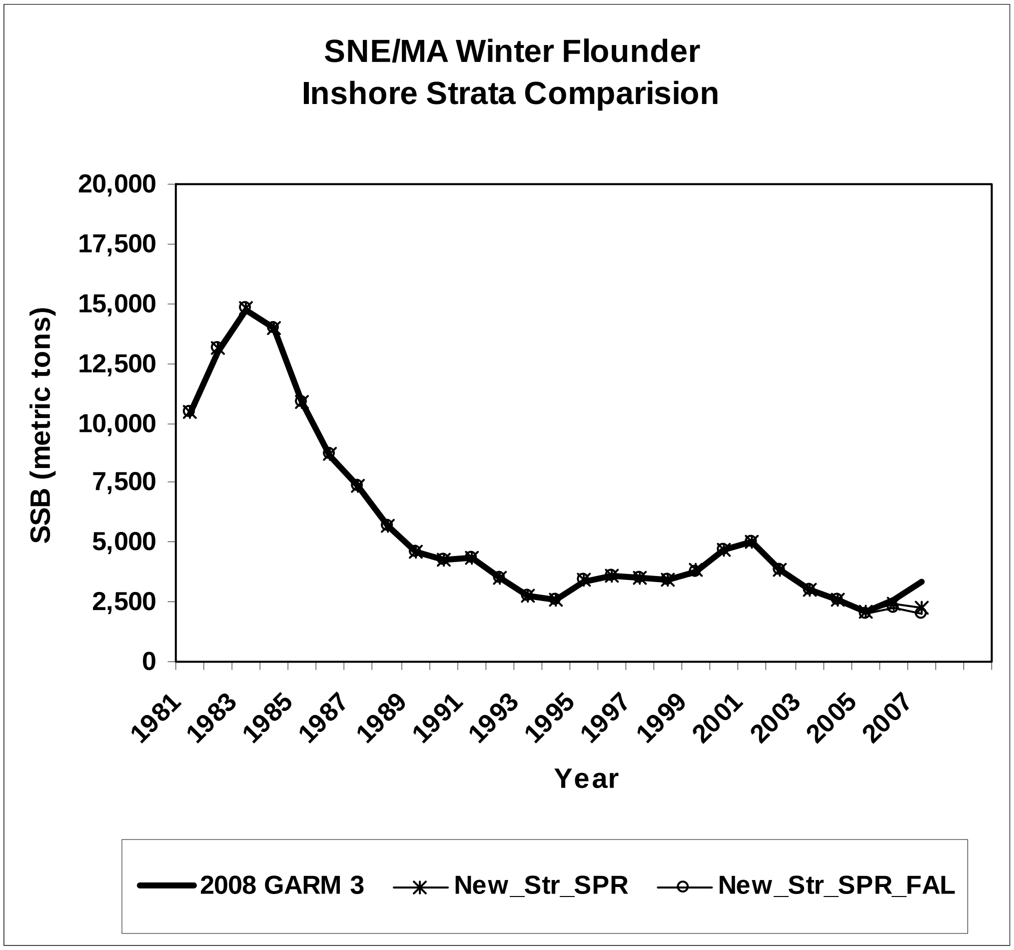
Impacts on the 2008 GARM 3 ADAPT VPA calibration

To evaluate the potential impact on the SNE/MA winter flounder assessment of the changes in the strata set and resulting NEFSC trawl survey spring and fall abundance indices, new versions of the 2008 GARM3 ADAPT VPA was constructed using the HBB strata set for the entire NEFSC time series (see previous figures). The “SPLIT” calibration configuration (breaking the NEFSC spring and fall, MADMF, RIDFW, CTDEP, DEDFW, and NYDEC survey series between 1993-1994) and the values of all the other survey data (state agency and NEFSC winter) remained the same.

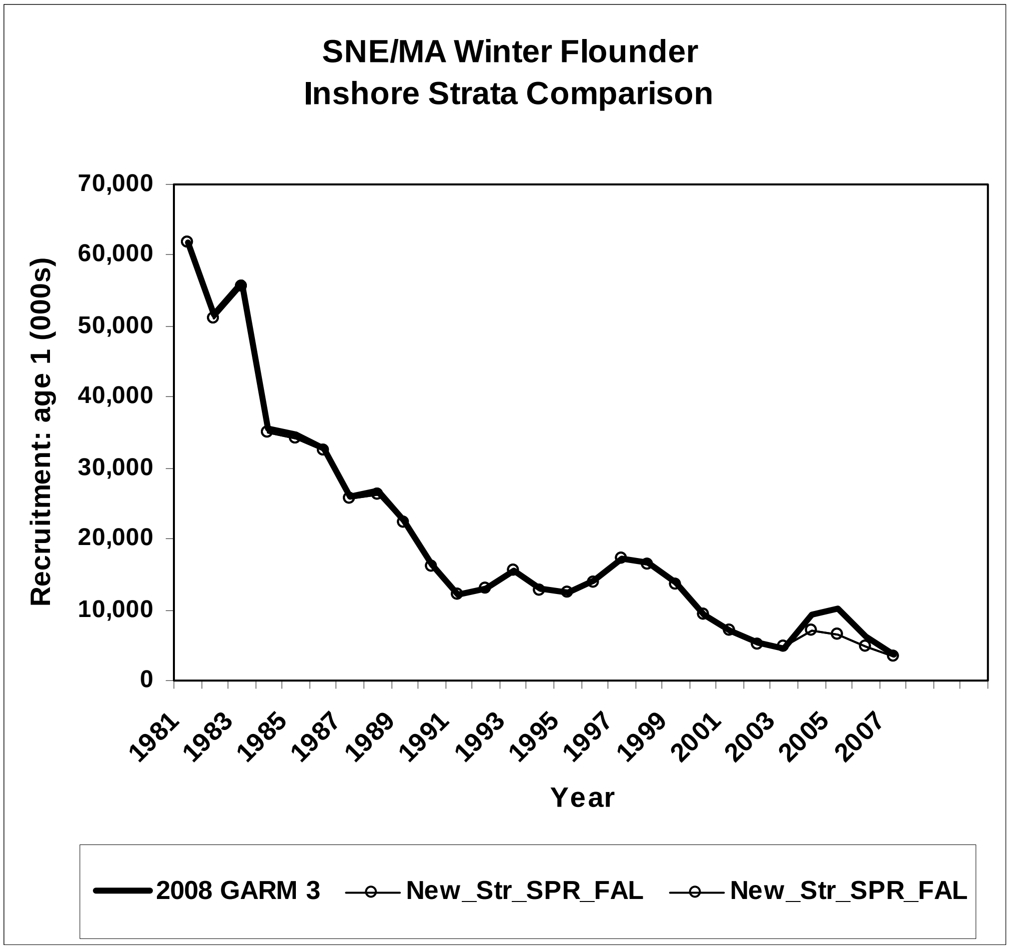
The impact of the new strata sets indices (either just Spring or both Spring and Fall) was negligible for the estimates of fully recruited Fishing Mortality (F, ages 4-5).



The impact of the new strata sets indices (either just Spring or both Spring and Fall) was more important for the estimates of SSB and R at the end of the time series. The 2007 estimate of SSB (2,006 mt)from the New_Str_SPR_FAL run including the HBB inshore strata set for both Spring and Fall series was 40% lower than the 2008 GARM 3 estimate (3,368 mt). This difference was due to differences in stock size estimates for the 2003-2005 year classes for the New-Str runs, which were 24% lower for the 2003 year class (2004 age 1), 37% lower for the 2004 year class (2005 age 1), and 21% lower for the 2005 year class (2006 age 1).



Given that the values of the early time series recruitments from SSB above 5,700 mt are virtually identical, and that mean weights and partial recruitment are virtually identical, there would be no effect on the calculated biological reference points from the strata set change for the 2008 GARM3 data. Going forward, the reference points may change as new data are added.



Conclusion

For the 2011 SARC 52 assessment, one choice is to retain the ALB strata set, and acknowledge that some fish historically sampled in the shallowest inshore strata sets will not be included in the 2009-2010 indices. Given past observations, this is likely to result in a slight negative bias in the 2009-2010 indices compared to the indices that would have been obtained had those strata been sampled. It should be noted that, however, that due to logistical issues (weather, mechanical breakdowns, fixed gear interference) the *specified* strata set (both inshore and offshore strata) has not always been completely sampled in the past (i.e., there is no absolute "consistently" *sampled* strata set).

The other choice is to adopt the indices from the HBB strata set, and acknowledge that a large number of fish historically sampled in the shallowest inshore strata sets will not be included in the time series, and also recognizing that the time series of consistently sampled strata begins in 1976. The advantage of this choice is that the entire series has a more "consistent" sample basis. The Working Group concluded that use of the consistent HBB strata set was best.

The Working Group also noted that winter flounder were rarely caught in the two deepest bands of offshore strata (e.g., 7-8, 11-12, etc.). The Working Group recommended that the NEFSC spring and fall survey series be revised to reflect a strata set consistent with that being sampled by the HBB (i.e., using only the deepest band of inshore strata) and excluding the two deepest bands of offshore strata (i.e., generally consistent with the set used for the Winter survey series). The revised strata set for SNE/MA winter flounder includes inshore strata 2, 5, 8, 11, 14, 17, 20, 23, 26, 29, 45, 46, and 56, and offshore strata 1, 2, 5, 6, 9, 10, 25, 69, 70, 73, and 74, for the years 1976 and later.

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SARC 52 Southern Demersal Working Group (SDWG)
Working Paper 3 – January 2011

Maturity

Background

In the 1999 SARC 28 review of the SNE/MA winter flounder stock assessment (NEFSC 1999), the SARC recommended re-examination of the maturity schedule used in the yield per recruit (YPR) and virtual population analyses (VPA) to incorporate any recent research results. The SARC 28 and previous assessments used the maturity schedule as published in O=Brien et al. (1993) for winter flounder south of Cape Cod, based on data from the MADMF spring trawl survey for strata 11-21 (state waters east of Cape Cod, Nantucket sound, Vineyard Sound, and Buzzards Bay) sampled during 1985-1989 (n = 301 males, n = 398 females). Those data provided estimates of lengths and ages of 50% maturity of 29.0 cm and 3.3 yr for males, and 27.6 cm and 3.0 yr for females, and the following estimated proportions mature at age. The female schedule (with the proportion at age 2 rounded down to 0.00) was used in the SARC 28 assessment YPR and VPA (NEFSC 1999).

Age	1	2	3	4	5	6	7+
Males	0.00	0.04	0.32	0.83	0.98	1.00	1.00
Females	0.00	0.06	0.53	0.95	1.00	1.00	1.00

In response to the SARC 28 recommendation, the 2002 SARC 36 (NEFSC 2003) examined NEFSC spring trawl survey data for the 1981-2001 period in an attempt to better characterize the maturity characteristics of the SNE/MA winter flounder stock complex. Data from the NEFSC survey included those judged in the SARC 28 assessment to comprise the SNE/MA complex from Delaware Bay to Nantucket Shoals: NEFSC offshore strata 1-12, 25 and 69-76, and inshore strata 1-29, 45-56. This was a much larger geographic area than that included in the MADMF survey data used in O=Brien et al. (1993). Data were analyzed in 5-6 year blocks (1981-1985, 1986-1990, 1991-1995, and 1996-2001) and for the entire time period (1981-2001), for each sex and combined sexes. Observed proportions mature at age were tabulated, and from those data maturity ogives at length and age were calculated to provide estimated proportions mature at age.

In general, the NEFSC maturity data indicated earlier maturity than the MADMF data, with L50% values ranging from 22-25 cm, rather than from 28-29 cm, and with ~50% maturity for age 2 fish, rather than ~50% maturity for age 3 fish. To investigate the apparent inconsistency between the MADMF and NEFSC maturity data, the two data sets were further compared over the same time periods (1985-1989, 1990-1995, 1996-2001) for common/adjacent survey strata (MADMF strata 11-12; NEFSC inshore strata 50-56 and offshore strata 10-12 and 25).

For comparable time periods and geographic areas, the NEFSC maturity data still consistently indicated a smaller size and younger age of 50% maturity than the MADMF data. NEFSC L50%

and A50% values range from 22-26 cm and about 2.0 yr, while the MADMF values range from 27-30 cm and about 3.0 yr. The difference in values from this comparison was not as large as for the full NEFSC data set extending southward to Delaware Bay, which incorporates components of the stock complex that mature at smaller sizes and younger ages. However, the difference was still nearly a full age class difference at 50% maturity.

Given that both length and age vary in the same direction, it seemed unlikely that the differences could be attributed to aging differences between the two data sets. Since the MADMF and NEFSC geographic areas in this comparison did not match exactly, the difference in maturity rates may be due to the extension of the NEFSC strata to somewhat deeper waters inhabited by fish that mature at a smaller size and younger age (inclusion of fish in offshore strata were necessary for sufficient sample size). Alternatively, for the size range of fish in question (20 to 30 cm length), it may be that immature and mature fish are segregated by area, with mature fish in that size interval tending to occupy inshore areas during the spring, with immature fish tending to remain offshore. Finally, there may be differences in the accuracy and consistency of interpretation of maturity stage between MADMF and NEFSC survey staff.

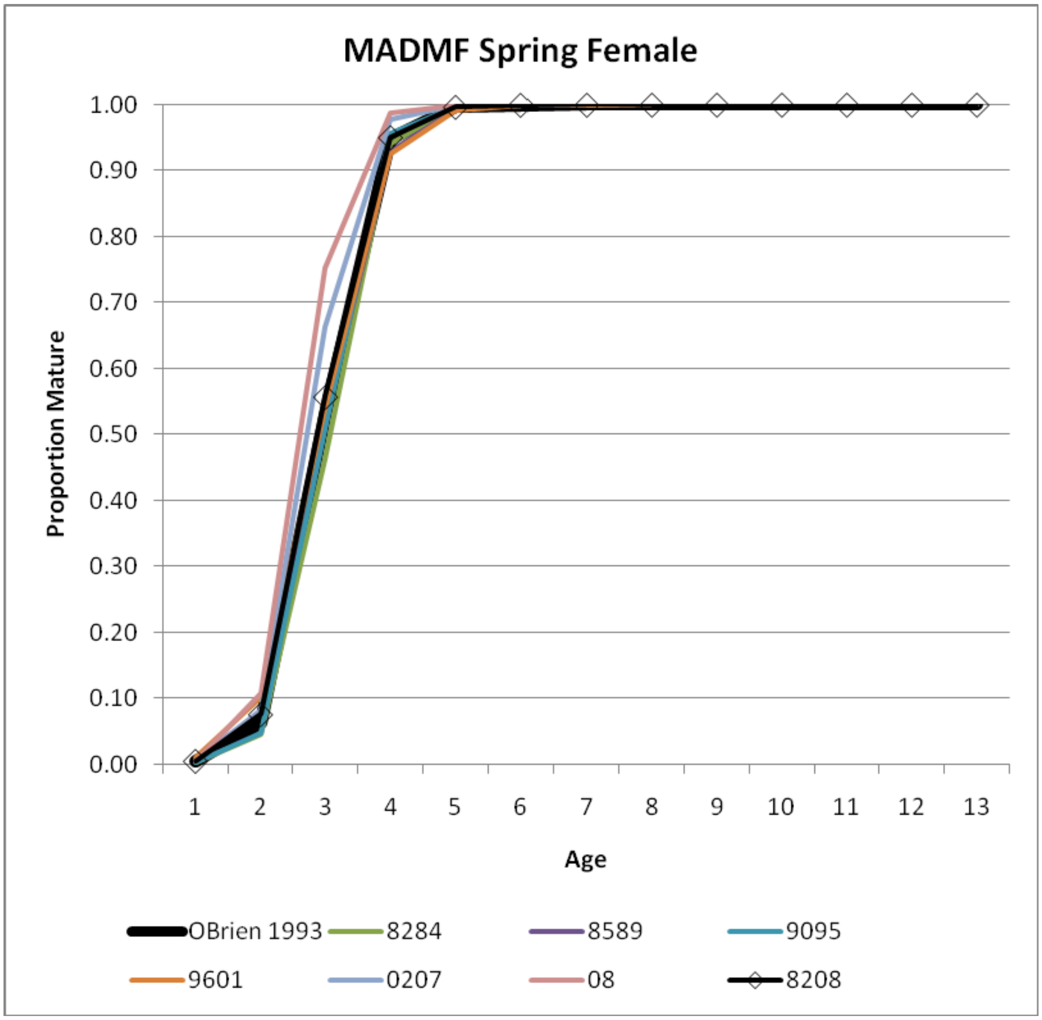
The 2002 SARC 36 considered these data and analyses and the possible causes for the noted inconsistencies, concluded that more detailed spatial and temporal analyses were needed before revisions to the maturity schedule can be adopted, and made a number of research recommendations for future winter flounder maturity work. The maturity at age schedule used in the 1999 SARC 28 assessment was retained in the 2002 SARC 36, 2005 GARM 2 (Mayo and Terceiro 2005), and 2008 GARM 3 (NEFSC 2008) assessments.

Since the 2002 SARC 36 assessment, the maturity data for SNE/MA winter flounder have been examined on an intermittent basis. Also, the recent work of McBride et al. (2010) examined the histological basis for maturity in winter flounder stocks, fit several maturation models to NEFSC sample data, and presented evidence for "skip" spawning in the GOM stock. This work revisits the MADMF and NEFSC maturity data for the SNE/MA, updates the 1999 SARC28 and 2008 GARM 3 examinations, and addresses some of the 2002 SARC 36 research recommendations relative to maturity.

MADMF and NEFSC data

The current work focuses on the maturity schedule for female fish, which in the past has been adopted as a proxy schedule for all the fish in the catch at age. In all cases, probit regression models assuming lognormal error were fit to the maturity data to estimate proportions mature at age. Both the MADMF and NEFSC maturity data have been recompiled and updated schedules computed.

The plot below presents the MADMF Spring survey data for the SNE/MA strata (09110-09210) updated through 2008, with year blocks for 1982-1984, 1985-1989 (corresponding to the data subset included in the O'Brien (1993) maturity schedule), 1990-1995, 1996-2001, 2002-2007, 2008, and all data combined for 1982-2008. The MADMF maturity data indicate a consistent pattern over the time series, with maturity at age 2 less than 10% across the time series, and some increase in maturity at age 3 (from about 50% to about 66%) in the 2002-2007 period.

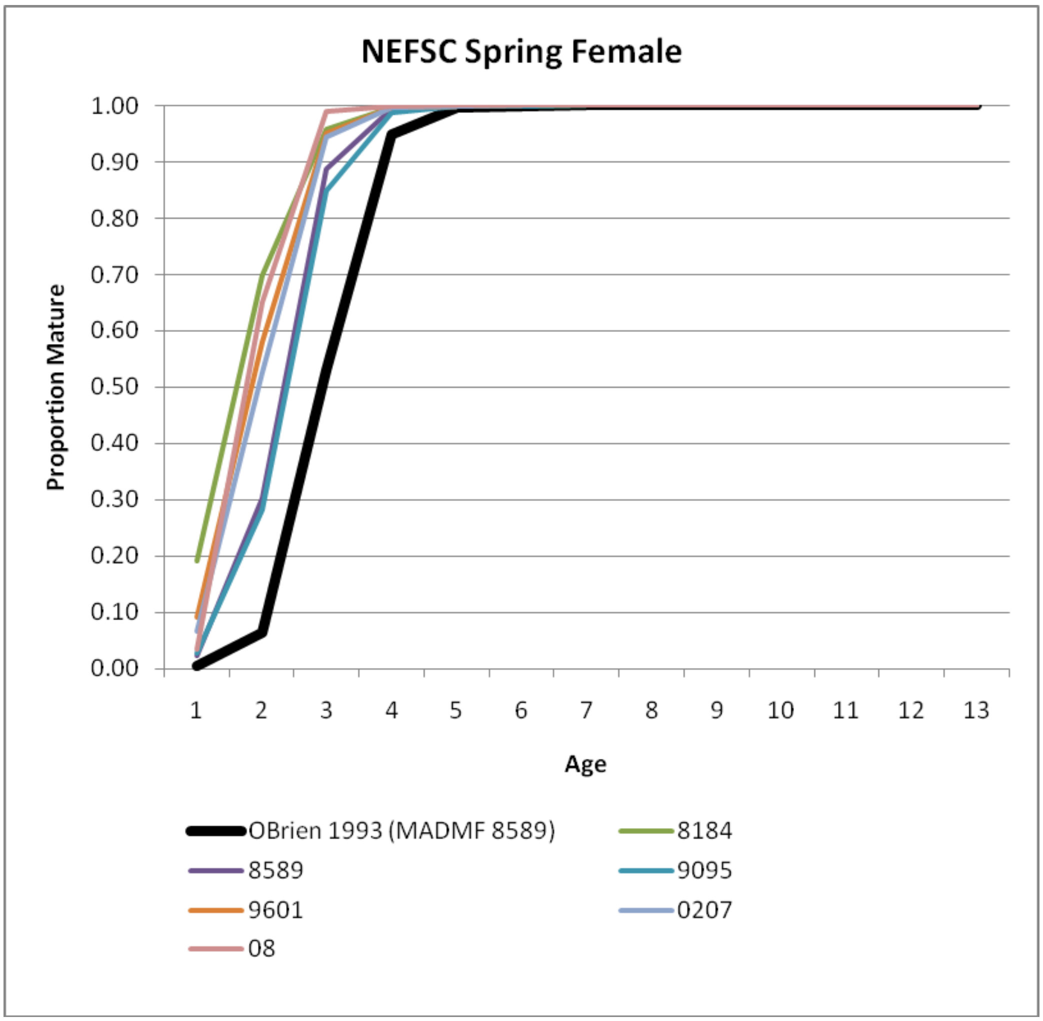


MADMF Spring Female
Proportion Mature
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1
2
3
4
5
6
7
8
9
10
11
12
13
Age
OBrien 1993
8284
8589
9095
9601
0207
08
8208

The table below shows that when all the MADMF Spring female maturity data are combined (1982-2008; 8208 in the plot legend) the resulting schedule is within 2-3% at age of the O'Brien (1993) schedule used in past assessments.

Age	1	2	3	4	5	6	7+
O'Brien 1993	0.00	0.06	0.53	0.95	1.00	1.00	1.00
Current work	0.00	0.08	0.56	0.95	1.00	1.00	1.00

The plot below presents the NEFSC Spring survey data for the all SNE/MA survey strata (0101-01220, 01250, 01690-01760, 03010-03260,03450-03560) updated through 2008, with year blocks for 1982-1984, 1985-1989 (corresponding to the data subset included in the O'Brien (1993) maturity schedule), 1990-1995, 1996-2001, 2002-2007, and 2008. The NEFSC Spring maturity data indicate a more variable pattern over the time series than the MADMF Spring data, with maturity at age 2 ranging from 28% to 70% across the time series, and maturity at age 3 at greater than 90% for the entire 1981-2008 period. The NEFSC Spring data continue to indicate an age of 50% maturity (A50) of about age 2, compared to A50 = age 3 for the MADMF Spring data.

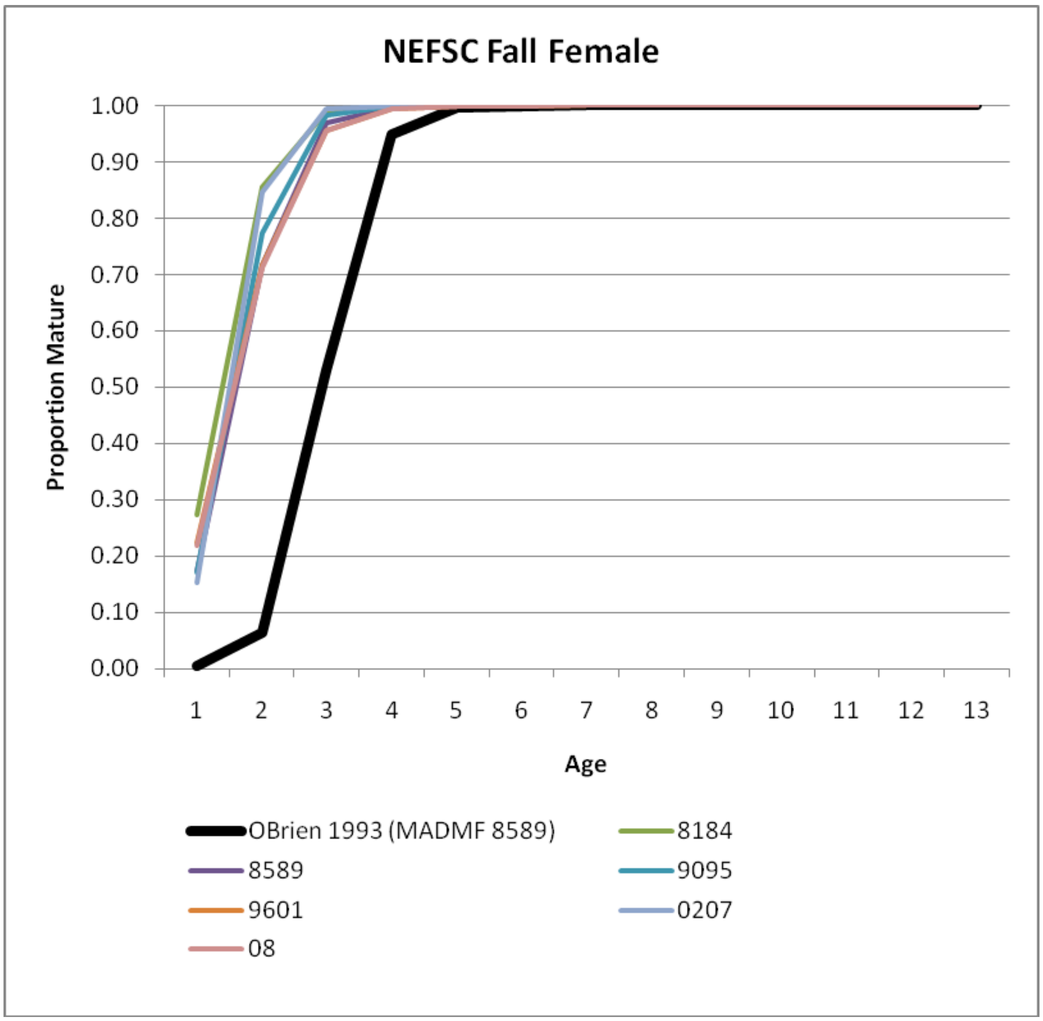


The 2002 SARC 36 assessment included Research Recommendations to "Evaluate the maturity at age of fish sampled in the NEFSC fall and winter surveys" and "Examine sources of the differences between NEFSC, MA and CT survey maturity (validity of evidence for smaller size or younger age at 50% maturity in the NEFSC data). Compare NEFSC inshore against offshore strata for differences in maturity. Compare confidence intervals for maturity ogives. Calculate annual ogives and investigate for progression of maturity changes over time. Examine maturity data from NEFSC strata on Nantucket Shoals and near George=s Bank separately from more inshore areas. Consider methods for combining maturity data from different survey programs."

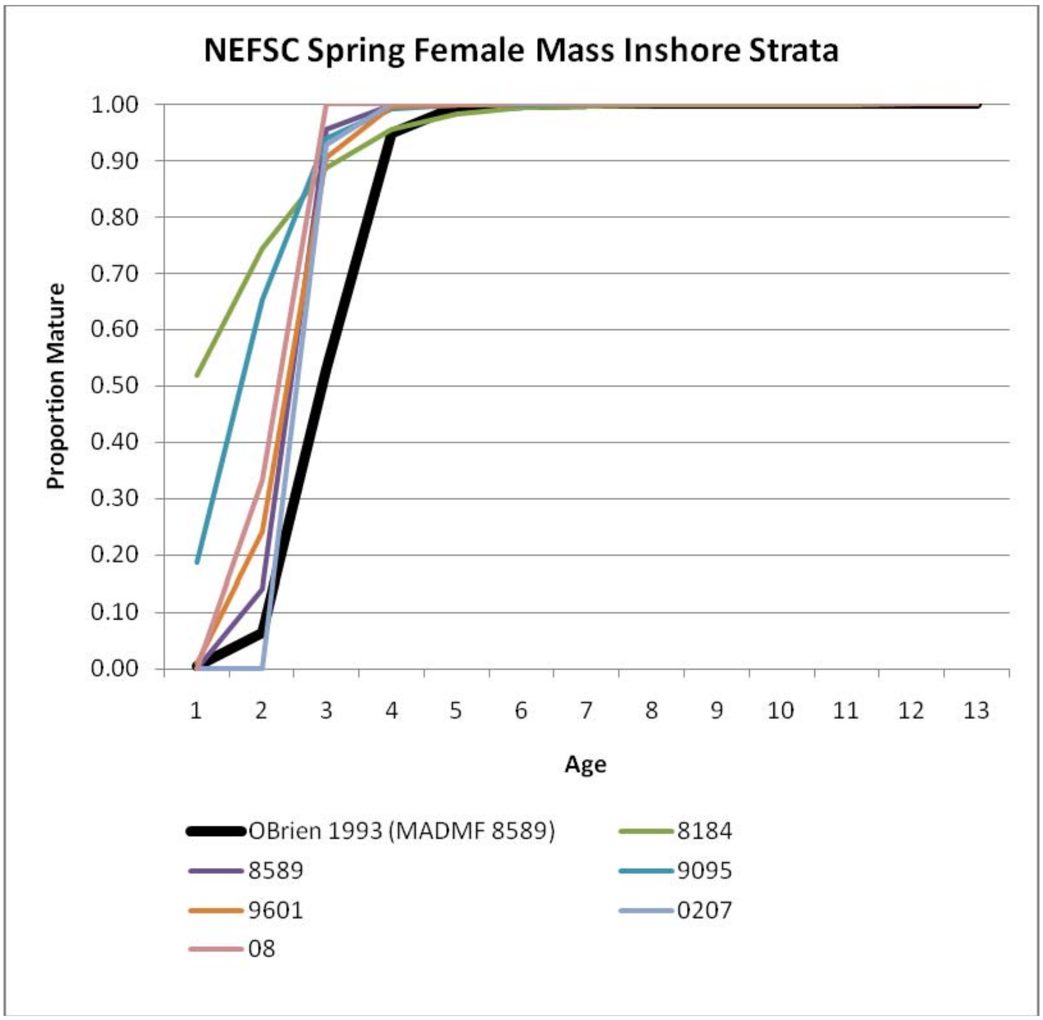
Some of these recommendations are addressed in this work. However, the NEFSC winter survey (1992-2007) age structures have not been processed, and so the associated maturity stages are not available in computerized form. Maturity data from the CTDEP trawl survey have not yet been compiled and provided in computerized form to the Working Group. As such, no analyses have been completed for those data.

Data from the NEFSC Fall survey, the NEFSC Spring survey for Massachusetts waters inshore strata (03550-03560; Nantucket Shoals), and the NEFSC Spring survey for Massachusetts water offshore strata (01090-01120 & 01250) have been compiled and analyzed in the same way as the NEFSC Spring and MADMF Spring survey full data sets, to respond to the Research Recommendations.

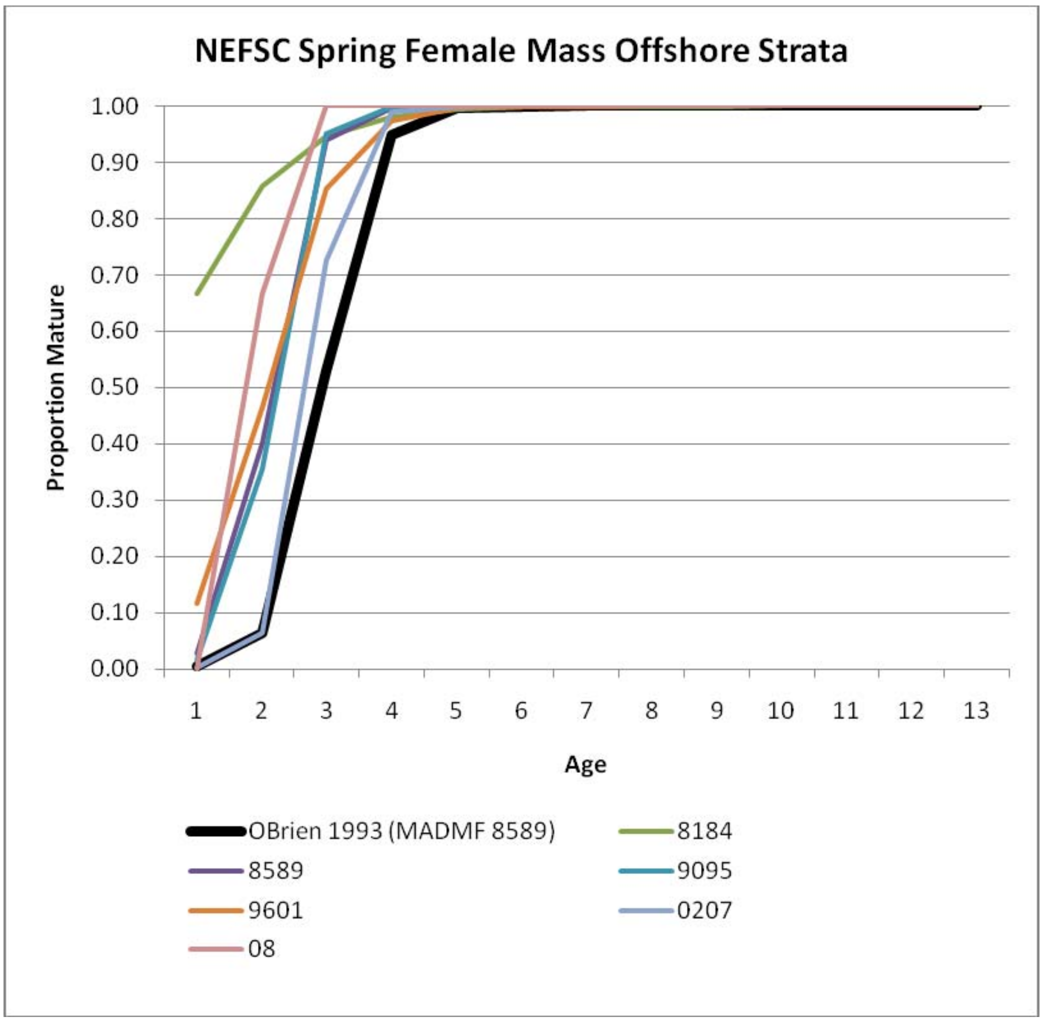
The plot below presents the NEFSC Fall survey data for the all SNE/MA survey strata (0101-01220, 01250, 01690-01760, 03010-03260,03450-03560) updated through 2008, with year blocks for 1982-1984, 1985-1989 (corresponding to the data subset included in the O'Brien (1993) maturity schedule), 1990-1995, 1996-2001, 2002-2007, and 2008. The NEFSC Fall maturity data indicate a more consistent pattern over the time series than the NEFSC Spring data, with maturity at age 2 ranging from 71% to 86% across the time series, and maturity at age 3 greater than 95% for the entire 1981-2008 period. Like the NEFSC Spring data, the NEFSC Fall data indicate an age of 50% maturity (A50) of about age 2, compared to A50 = age 3 for the MADMF Spring data.



The plot below presents the NEFSC Spring survey data for Massachusetts waters Inshore strata, which are a band of strata outside (and deeper) than the adjacent MADMF survey strata on Nantucket Shoals and Outer Cape Cod. Only NEFSC Massachusetts waters Inshore strata 03550 and 03560 were consistently sampled during the 1981-2008 period. As with the other sets, data updated through 2008, with year blocks for 1982-1984, 1985-1989 (corresponding to the data subset included in the O'Brien (1993) maturity schedule), 1990-1995, 1996-2001, 2002-2007, and 2008. The NEFSC Spring Massachusetts waters Inshore maturity data indicate a more variable pattern over the time series than the full NEFSC Spring data set, with maturity at age 2 ranging from 0% to 74% across the time series, and maturity at age 3 from 89% to 100%. Like the full NEFSC Spring data set, the NEFSC Massachusetts Inshore data indicate an age of 50% maturity (A50) of about age 2, compared to A50 = age 3 for the MADMF Spring data.



The plot below presents the NEFSC Spring survey data for Massachusetts waters Offshore strata, which includes strata 01090-01120 and 01250, in waters south of Nantucket Shoals and east of Outer Cape Cod. As with the other sets, data updated through 2008, with year blocks for 1982-1984, 1985-1989 (corresponding to the data subset included in the O'Brien (1993) maturity schedule), 1990-1995, 1996-2001, 2002-2007, and 2008. The NEFSC Spring Massachusetts waters Offshore maturity data indicate a more variable pattern over the time series than the full NEFSC Spring data set, with maturity at age 2 ranging from 6% to 86% across the time series, and maturity at age 3 from 73% to 100%. Like the full NEFSC Spring data set, the NEFSC Massachusetts Inshore data indicate an age of 50% maturity (A50) of about age 2, compared to A50 = age 3 for the MADMF Spring data.



Given the respective characteristics of the MADMF Spring and various strata set combinations of the NEFSC Spring and Fall maturity, and the indications from the McBride et al. (2010) histological work that age 2 fish are likely not mature, the Working Group concluded that the MADMF Spring survey data provide the best macroscopic evaluation of the maturity stage for SNE/MA winter flounder. The Working Group recommends that the MADMF Spring data 1981-2008 time series maturity estimates at age (age 1 - 0%; age 2 – 8%; age 3 – 56%; age 4 – 95%, age 5 and older – 100%) be used in the 2011 SARC 52 assessment.

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Response to 2008 GARM3 Research Recommendations for winter flounder

Introduction

The primary Research Recommendations from the 2008 GARM3 assessments for winter flounder were: "Assessment approaches needs [*sic*] to be explored that consider all three Winter Flounder stocks as a stock complex within which there is significant interaction amongst the individual stock components." and "The Panel also had concerns about the unit stock, not only for this stock, but for all of the Winter Flounder stocks assessed. It recommended an analysis of Winter Flounder as a stock complex, rather than as individual stocks, be undertaken" (NEFSC 2008).

The stocks are defined as they are now based on a) historical tagging studies show low rates of exchange (a few percent) between the stock areas (Howe and Coates 1975; Pereira *et al*. 1999), b) differences in the growth rates between the stocks, with GBK fish growing faster, GOM fish growing slower, and SNE fish growing at an intermediate rate (How and Coates 1975; Lux 1973; NEFSC 2008), c) differences in the rates of maturation (NEFSC 2008), d) differences in meristics, mainly fin ray counts (Lux *et al*. 1970), and e) fishery "integration" of catches from potential bay/estuarine specific-stocks in the GOM and the SNE "complexes."

Briefly, the status of the three stocks as of the 2008 GARM3 (catches through 2007) is as follows:

GOM: at 29% of BMSY, at 1.5 times FMSY - but note the assessment was not accepted as the basis for management, because of residual error trends and a severe retrospective pattern in the ADAPT VPA - therefore stock status is currently "unknown"

GBK: Overfished, at 31% of BMSY; overfishing, at 8% above FMSY; retrospective pattern acceptable

SNE: Overfished, at 9% of BMSY; overfishing, at 2.6 times FMSY; retrospective pattern acceptable using a "split" calibration configuration (most surveys broken into 2 series at 1993/1994)

Combining the assessments

This first step in responding to the Research Recommendations was to aggregate all 3 stocks together in “All Stocks” winter flounder ADAPT VPA (back-calculating model) - i.e., to assume 100% "interaction". The three catch at age matrices from the GARM3 assessments were combined into a single catch at age matrix; aggregate mean weight and maturity matrices (weighted by the respective input catch numbers at age) were also compiled. The survey calibration data were input as in the separate stock assessments.

The GOM survey data included NEFSC spring and fall, MADMF spring and fall, and Seabrook (NH) indices at age. The GBK survey data included NEFSC spring and fall and Canada DFO spring indices at age. The SNE/MA survey data included NEFSC winter, spring, and fall, MADFW spring, RIFDFW spring, CTDEP spring, NYDEC, and NJDFW indices at age.

ADAPT VPA model

The ADAPT VPA model was configured with "splits" in the survey time series as in the 2008 GARM3 GOM and SNE/MA assessments. The "split" configuration generally reduced the number and magnitude of error residual patterns for the survey calibration indices. As a result of the combined split configuration, however, newly significant residual patterns developed for some of the survey series, especially those for GBK series which were not split, generally from blocks of negative residuals early (1980s) in the time series to blocks of positive residuals after the mid-1990s. The GBK NEFSC fall survey indices developed these patterns for ages 4 and older (Figures 1-2).

The ALL_WFL_VPA exhibited a reduced retrospective pattern compared to those in the GARM3 GOM and SNE assessments (recent overestimation of SSB ranging from 8-15%; underestimation of F ranging up to 22%; Figures 3-4).

Stock size and fishing mortality rate estimates from the ALL_WFL_VPA are a "blend" of the three GARM assessment results, as might be expected. SSB declines from a peak of about 35,000 mt in 1982 to a low point in 1994 at about 6,700 mt, increases to about 15,000 mt in 2000-2001, and then declines to 9,500 mt by 2007 (Figure 5). Fishing mortality (F, ages 4-5) increases from about 0.60 in 1982-1983 to a peak of 1.28 in 1993, before generally decreasing to 0.38 by 2007 (Figure 5). Recruitment peaked at 71-72 million age 1 fish in 1982-1983, and then generally declined to less than 30 million fish since 1998 (Figure 5).

The 2007 SSB estimates from the 2008 GARM3 assessments total about 9,400 mt, while the ALL_WFL_VPA estimate is 9,538 mt, about 2% higher.

GOM:	1,000 mt
GBK:	4,964 mt
SNE:	3,368 mt
Total:	9,432 mt
ALL_WFL_VPA:	9,539 mt

The 2007 F (ages 4-5) estimates from the 2008 GARM3 assessments provide a SSB-weighted average of 0.43, while the ALL_WFL_VPA estimate is 0.38, about 12% lower.

GOM:	0.42
GBK:	0.28
SNE:	0.65
Total (SSB weighted):	0.43
ALL_WFL_VPA:	0.38

The next step was to calculate reference points and compare them to the ALL_WFL_VPA 2007 estimates. As in the GARM3 assessments, a yield and SSB per recruit analysis was used to estimate F40% as the Fthreshold proxy for FMSY. As in the GARM3 SNE/MA assessment, one hundred year projections using the recruitment for the "high-stanza" year classes (recruitment at SSB greater than 15,000 mt, an average of about 52 million age 1 fish; Figure 6) was then used to estimate MSY and SSB40% as the proxy for BMSY. Average mean weights and partial recruitment at age for 2005-2007 were used as inputs for both analyses.

F40% was estimated at 0.262; SSB40% was estimated at 70,699 mt, and MSY was estimated at 17,028 mt. The ALL_WFL_VPA results indicate that the 2007 SSB was at 14% of BMSY (overfished), and that the 2007 F was 1.5 times FMSY (overfishing).

Below is a comparison with the three GARM3 assessment reference point results.

SSB40% = BMSY

GOM:	3,792 mt
GBK:	16,000 mt
SNE:	38,761 mt
Total:	58,553 mt
ALL_WFL_VPA:	70,699 mt

MSY

GOM:	917 mt
GBK:	3,500 mt
SNE:	9,742 mt
Total:	14,159 mt
ALL_WFL_VPA:	17,028 mt

F40% = FMSY

GOM:	0.28
GBK:	0.26
SNE:	0.25
Total (SSB weighted):	0.26
ALL_WFL_VPA:	0.26

Conclusion

This exercise violates the existing assumptions of stock structure based on information about the biology, migration patterns, and fishing patterns for winter flounder. The ALL_WFL_VPA results were perhaps to be expected, as the estimates are to some degree a "blend" of the three independent stock unit inputs. Similar to the experience with the 2008 GARM3 GOM and SNE/MA assessments, the "Split" run configuration reduced trends in residuals and the retrospective pattern. Aggregation of the three stock units resulted in a larger aggregate spawning stock biomass reference point and MSY estimate, while the aggregate stock status remained overfished with overfishing occurring in 2007.

The Working Group concluded that the information available on winter flounder stock structure provides strong support for the current three stock units, and that attempts to model those units as a single complex is not worth pursuing further. The Working Group does not believe that the benefits from the single-stock analysis (a single analysis instead of three; reduced retrospective pattern; ability to model the Gulf of Maine unit within the complex) are sufficient to ignore the observed differences in biological traits (growth, maturity, fecundity) that affect the interpretation of the spawning stock reproductive potential of the three current units.

Further research could pursue use of a more complex model (e.g., Stock Synthesis) to maintain separate fishery and survey catch for the three current stock units, while allowing a small amount (a few percent) exchange between the stock units based on information from historical tagging. This approach would also respond to SARC 52 Term of Reference 8C.

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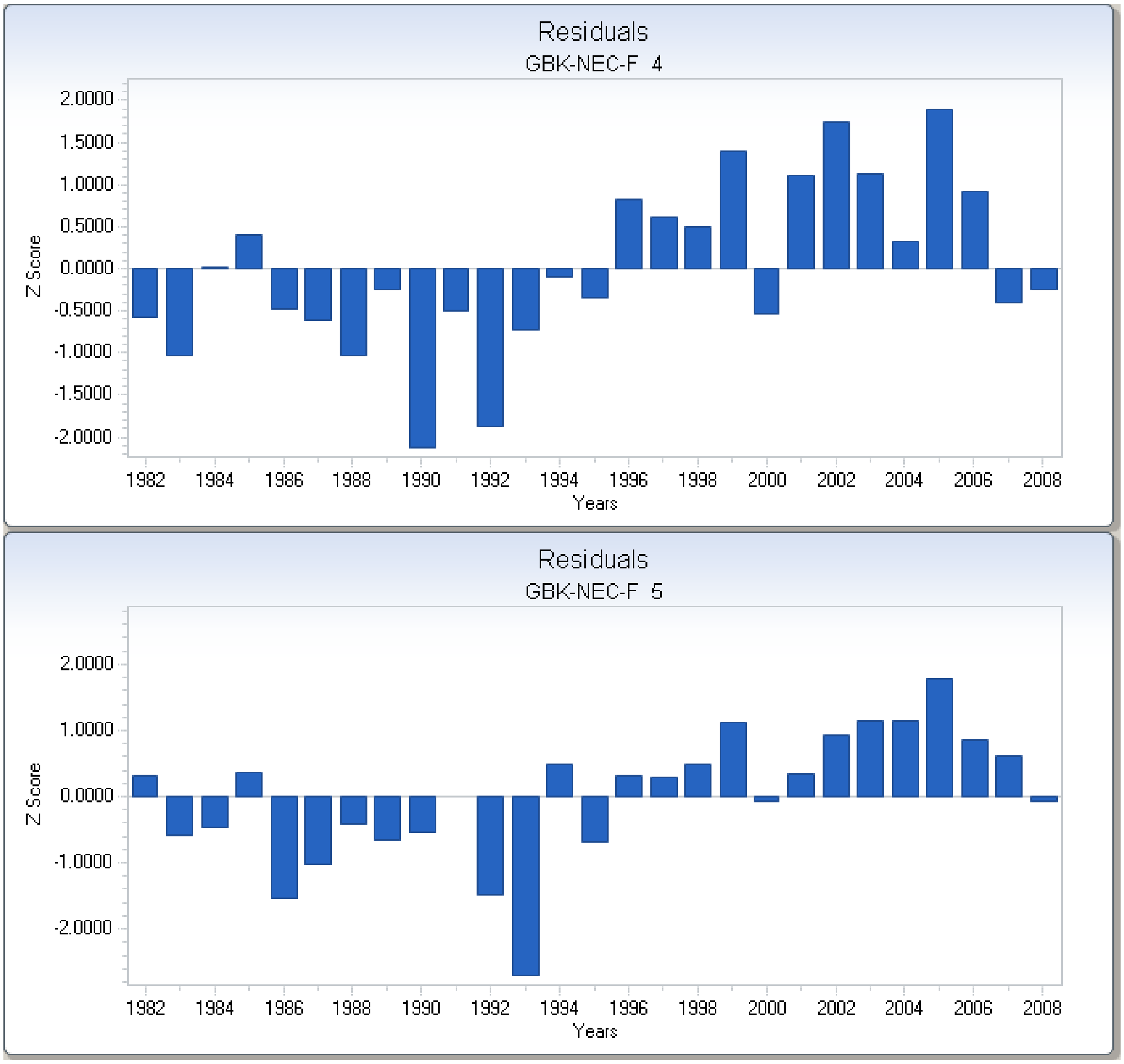

Figure 1. ALL_WFL_VPA GBK NEFSC fall survey residuals for ages 4-5.

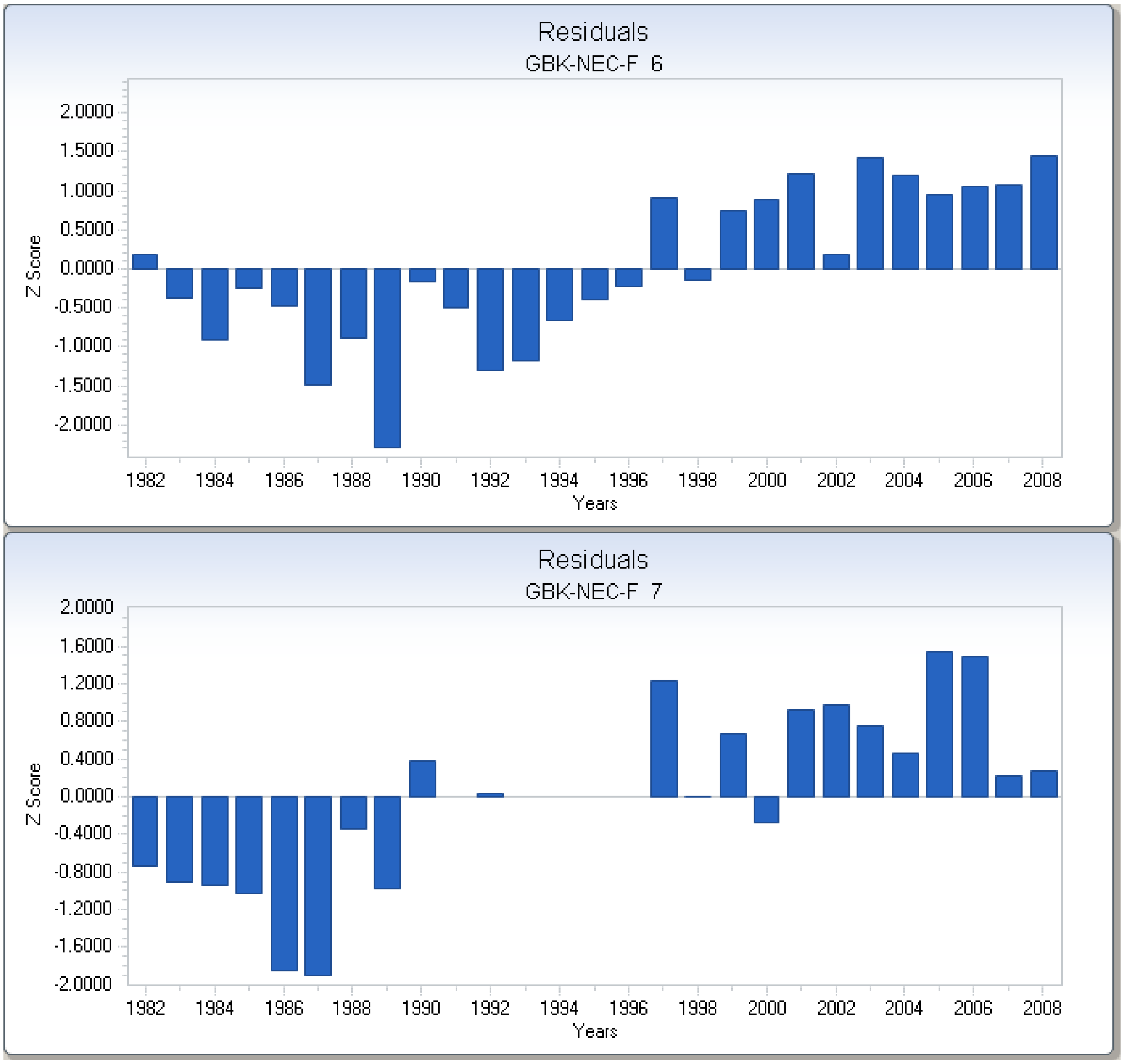

Figure 2. ALL_WFL_VPA GBK NEFSC fall survey residuals for ages 6-7.

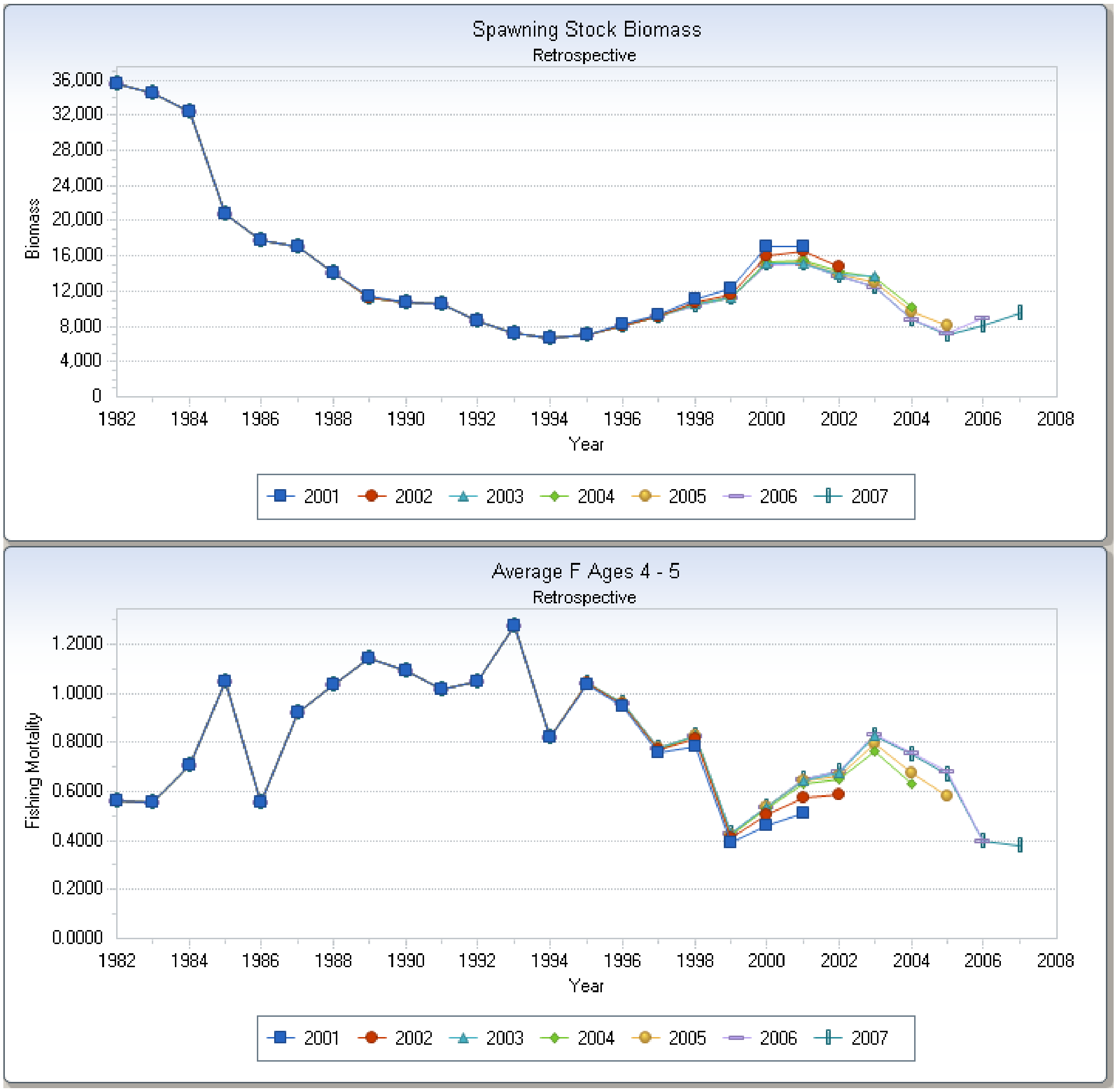

Figure 3. Retrospective patterns Absolute Differences in SSB and F from the ALL_WFL_VPA run.

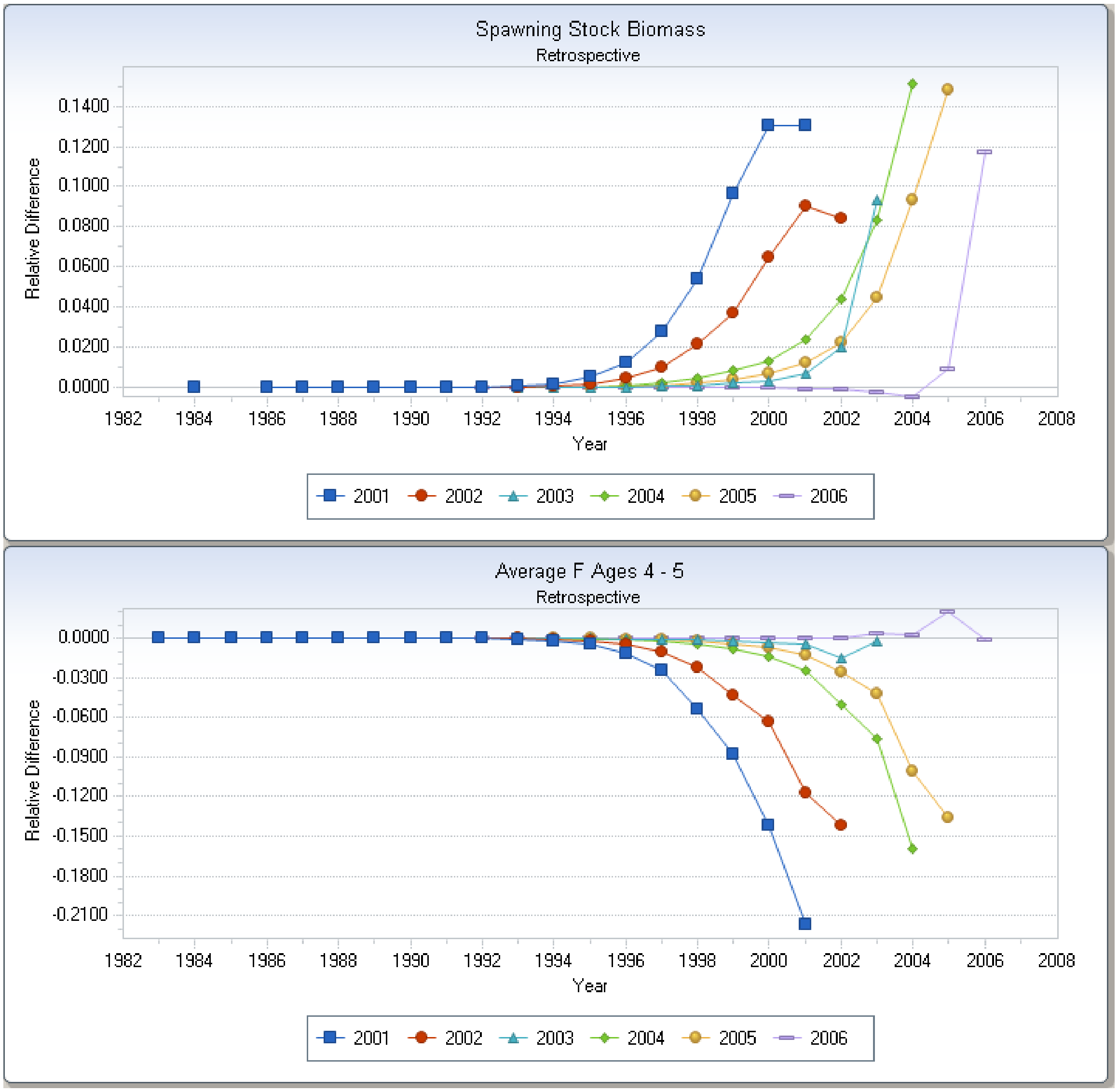

Figure 4. Retrospective pattern Relative Differences in SSB and F from the ALL_WFL_VPA run.

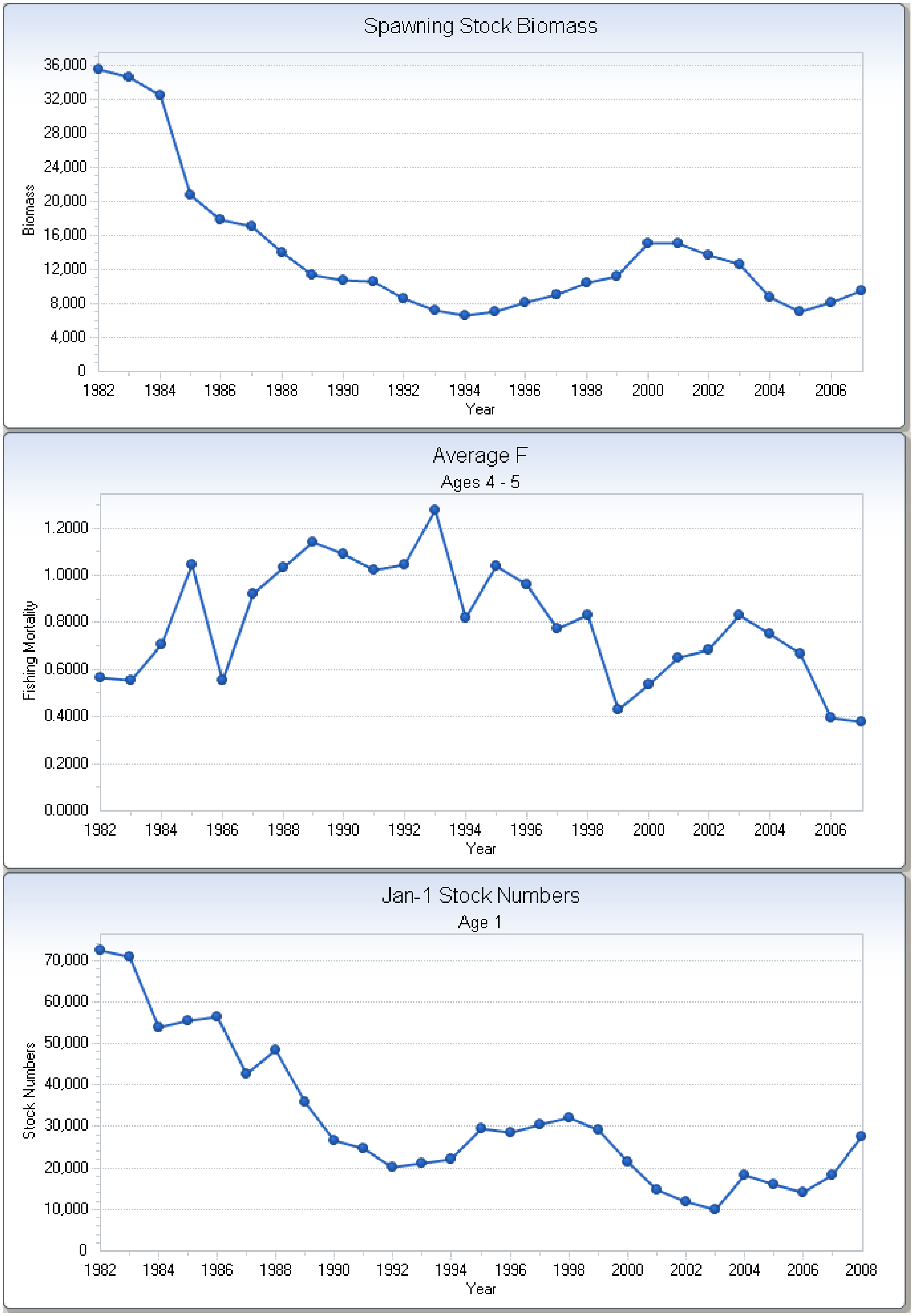

Figure 5. Trends in SSB, F, and R at age 1 from the ALL_WFL_VPA run.

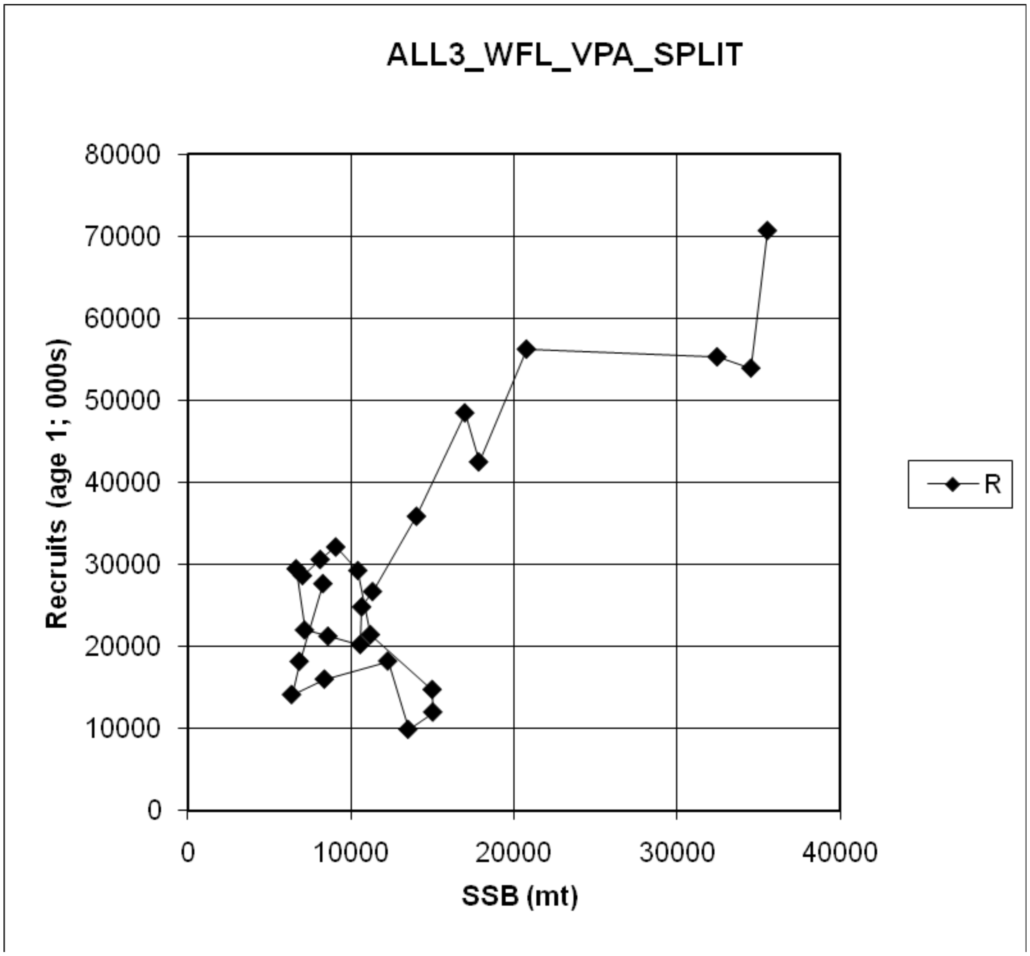

Figure 6. Stock-recruitment scatterplot for the ALL_WFL_VPA run. The six largest recruitments (averaging 52 million age 1 fish) were used in estimating the BMSY proxy = SSB40% for the FMSY proxy = F40% = 0.262.

SNE/MA Winter Flounder TOR 4

TOR 4: "Perform a sensitivity analysis which examines the impact of allocation of catch to stock areas on model performance (in TOR 5)."

The SARC Southern Demersal Working Group (SDWG) interpretation of the NRCC's intent is that we should consider the variance of the commercial landings due to the 1995 and later area-allocation scheme, use that as the basis for the magnitude of landings that might be lost or gained from the stock-specific assessments, and then run the assessment models with those changes and report the results. For all three stocks the catch consists of multiple components. For the SNE/MA stock, for example, the catch consists of 4 components. The commercial landings have a calculated Proportional Standard Error (PSE; due to the aforementioned commercial landings area-allocation procedure; available for 1995 and later years, with the mean of those years substituted for 1981-1994) ranging from <1% to about 5%; the commercial discard PSEs range from 17-35% (available for 1994-2010, mean of those years substituted for 1981-1993); the recreational landings PSEs range from 17-40%; and the recreational discard PSEs range from 18-57%. Because the PSEs for the commercial landings are low, and the commercial landings account for about two-thirds of the total catch, the total catch weighted-average annual PSEs range from 3.1-21.3%, and averages 8% (unweighted) for the 1981-2010 time series (Table 4.1).

Exercise 1

In Exercise 1, following the SDWG interpretation of how to address TOR 4, the numbers in the catch at age were increased by the non-uniform, annual average PSE values (i.e., about one Standard Error), the 2008 GARM 3 assessment model was run and Biological Reference Points (BRPs) estimated, and those results compared with the current values. For the SNE/MA stock, this step increased the numbers in the catch at age (CAA) by the annual average PSE values (ranging from a maximum of CAA*1.137 in 1985 to a minimum of CAA*1.030 in 2001), portraying the impact of an annually varying negative bias (i.e., the catch is underestimated by one PSE each year) in the current CAA. Figures 4.1-4.3 show how the F at ages 4-5 was nearly unchanged (on average, scaled down by 1%), while the SSB and R scaled up by an average of 7%.

Next, the Plus-One-PSE run BRPs were calculated and stock status evaluated. The partial recruitment pattern was unchanged (to 2 decimal places) from the 2008 GARM 3 model, so the FMSY proxy = F40% = 0.248 was unchanged (mean weights and maturity were also unchanged). The new, 7% higher recruitment values (8 highest values in the S-R pair series) were used in the 2008 GARM3 projection to calculate a new BMSY = SSB40%, estimated to be 42,096 mt, about 9% higher than 2008 GARM3 estimate of 38,761 mt. The new MSY was estimated to be 10,581 mt, about 9% higher than GARM3 estimate of 9,742 mt.

Based on the Plus-One-PSE run, stock status was still overfished (3,499 mt; 8% of BMSY) with overfishing (0.640; 2.6 times FMSY) in 2007. The overall conclusion was that the application of a relatively minor but varying "bias-correction" in one direction in this sensitivity exercise will provide biomass estimates and BRPs that scale up or down by about the same average magnitude.

Exercise 2

After review of the Exercise 1 results, the SDWG noted that the 2008 GARM 3 Data Panel commented that "…the highest percent of total landings that required matching at level B, C and D was 13% and thus inter-stock reallocations were not considered significant. While there is little impact on landings allocations amongst stocks overall, there could be issues in the case of small stocks adjacent to larger ones." The current work for the winter flounder stocks indicates that in recent years, in particular 2009 and 2010, a higher percentage is being allocated at the "no direct dealer to VTR match" area-allocation levels (B, C, and D; Table 4.2; note that 2010 data are preliminary). It was also noted that the variance calculations do not account for other errors that might occur even for dealer-to-VTR matched trips (level A). These important sources of error can include:

a) Misreporting of the true statistical area, particularly for multi-day trips
b) Errors in the dealer data related to the assignment of landings to permits (due to vessel sales or other permit transactions), which may result in landings reported in a port in a different stock area

The SDWG concluded that the calculated variance of the area-allocated commercial landings likely underestimates the true error. After taking these issues into consideration, the SDWG concluded that a tripling (3X) of the calculated average PSE would provide a useful upper bound on the degree of uncertainty in the estimated catch. For the SNE/MA stock, this step increased the numbers in the catch at age (CAA) by three times (3X) the annual average PSE values (ranging from a maximum of CAA*1.412 in 1985 to a minimum of CAA*1.091 in 2001), portraying the impact of an annually varying negative bias (i.e., the catch is underestimated by 3 PSE each year) in the current CAA. Figures 4.4-4.6 show how the F at ages 4-5 was nearly unchanged (on average, scaled down by 1%), while the SSB and R scaled up by an average of 24%.

Next, the Plus-3-PSE run BRPs were calculated and stock status evaluated. The partial recruitment pattern was unchanged (to 2 decimal places) from the 2008 GARM 3 model, so the FMSY proxy = F40% = 0.248 was unchanged (mean weights and maturity were also unchanged). The new, 24% higher recruitment values (8 highest values in the S-R pair series) were used in the 2008 GARM3 projection to calculate a new BMSY = SSB40%, estimated to be 49,828 mt, about 29% higher than 2008 GARM3 estimate of 38,761 mt. The new MSY was estimated to be 12,528 mt, about 29% higher than GARM3 estimate of 9,742 mt. Based on the Plus-3-PSE run, stock status was still overfished (3,835 mt; 8% of BMSY) with overfishing (0.640; 2.5 times FMSY) in 2007. The overall conclusion was that the application of a relatively large but varying "bias-correction" in one direction in this sensitivity exercise will provide biomass estimates and BRPs that scale up or down by about the same average magnitude.

Table 4.1 SNE/MA Winter Flounder Catch (metric tons) and Proportional Standard Error (PSE)

Year	Comm Land	COML PSE 1995-2010	Comm Disc	COMD PSE 1994-2010	Rec Land	RECL PSE 1981-2010	Rec Disc	RECD PSE 1981-2010	Total Catch	Weighted PSE
1981	11,176	0.8	1,343	27	3,154	18	91	25	15,764	6.6
1982	9,438	0.8	1,149	27	3,493	36	63	48	14,143	11.8
1983	8,659	0.8	1,311	27	3,485	17	127	25	13,582	7.7
1984	8,882	0.8	986	27	5,510	20	148	21	15,526	9.5
1985	7,052	0.8	1,534	27	5,075	27	230	30	13,891	13.7
1986	4,929	0.8	1,273	27	2,949	20	66	23	9,217	10.7
1987	5,172	0.8	950	27	3,169	18	61	23	9,352	9.4
1988	4,312	0.8	904	27	3,510	17	69	21	8,795	10.1
1989	3,670	0.8	1,404	27	1,792	24	49	57	6,915	12.5
1990	4,232	0.8	673	27	1,063	18	31	18	5,999	6.9
1991	4,823	0.8	784	27	1,184	19	51	24	6,842	7.1
1992	3,816	0.8	511	27	387	16	15	23	4,729	4.9
1993	3,010	0.8	457	27	813	30	31	27	4,311	9.3
1994	2,128	0.8	341	35	594	21	29	26	3,092	8.7
1995	2,593	0.4	159	30	650	23	32	23	3,434	6.3
1996	2,783	0.5	175	29	714	20	30	29	3,702	5.8
1997	3,548	0.7	277	19	627	25	31	29	4,483	5.4
1998	3,138	0.7	173	32	290	30	13	36	3,614	4.7
1999	3,349	0.5	62	27	320	25	14	27	3,745	3.1
2000	3,704	0.4	148	29	870	25	32	35	4,754	6.0
2001	4,556	0.4	28	29	549	23	14	25	5,147	3.0
2002	3,084	0.6	93	35	223	33	12	34	3,412	3.8
2003	2,308	0.5	185	30	323	22	11	35	2,827	5.0
2004	1,636	1.2	84	23	214	23	8	37	1,942	4.7
2005	1,320	1.2	106	27	124	37	14	30	1,564	6.0
2006	1,720	0.5	152	20	136	40	16	34	2,024	4.9
2007	1,628	0.6	115	17	116	40	5	42	1,864	4.2
2008	1,113	0.8	109	23	73	30	3	36	1,298	4.4
2009	271	2.3	165	35	86	29	9	28	531	17.2
2010	174	4.5	153	34	28	51	8	40	363	21.3
Means	3941	0.9	527	27.5	1384	25.9	44	30.4	5895	7.8

Table 4.2. Percent of landings by Area-Allocation level (ALEVEL A,B,C,D, X and unallocated) for SNE/MA winter flounder.

	1995	1996	1997	1998	1999	2000	2001	2002	2003
A	63.6%	64.5%	60.8%	63.8%	66.4%	71.1%	69.9%	64.0%	69.6%
B	21.1%	19.4%	23.6%	19.3%	21.9%	18.9%	19.8%	24.2%	15.5%
C	6.5%	8.1%	8.5%	9.4%	5.9%	3.9%	5.2%	7.4%	9.5%
D	0.2%	0.2%	0.1%	0.1%	0.1%	0.4%	0.7%	0.3%	0.6%
Unallocated	8.6%	7.8%	6.9%	7.4%	5.8%	5.7%	4.4%	4.1%	4.8%
Grand Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

	2004	2005	2006	2007	2008	2009	2010	Total
A	59.2%	62.4%	70.8%	71.0%	69.3%	57.2%	27.8%	66.1%
B	20.6%	14.9%	16.6%	19.8%	25.7%	16.4%	43.4%	20.4%
C	4.6%	9.4%	5.2%	5.5%	3.8%	21.6%	19.0%	6.8%
D	9.6%	8.6%	3.0%	0.3%	0.7%	2.4%	9.3%	1.2%
Unallocated	6.0%	4.7%	4.3%	3.5%	0.5%	2.3%	0.5%	5.5%
Grand Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

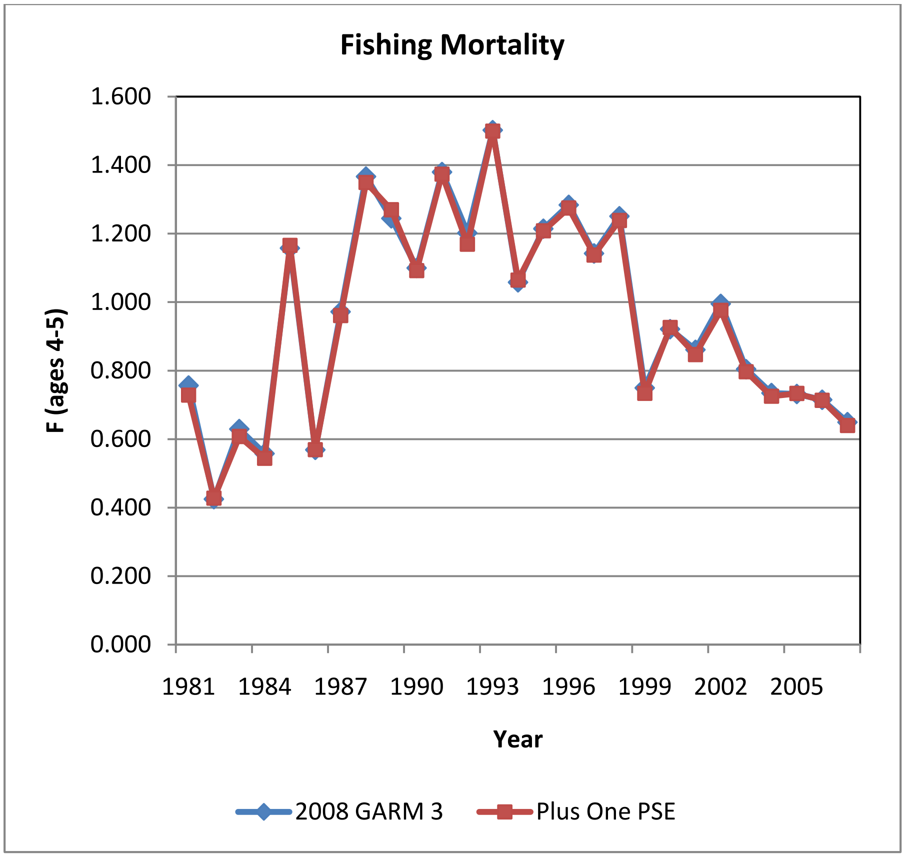

Figure 4.1. Comparison of fishing mortality rate (F ages 4-5) estimates from the 2008 GARM 3 assessment model and the Plus-One-PSE model run.

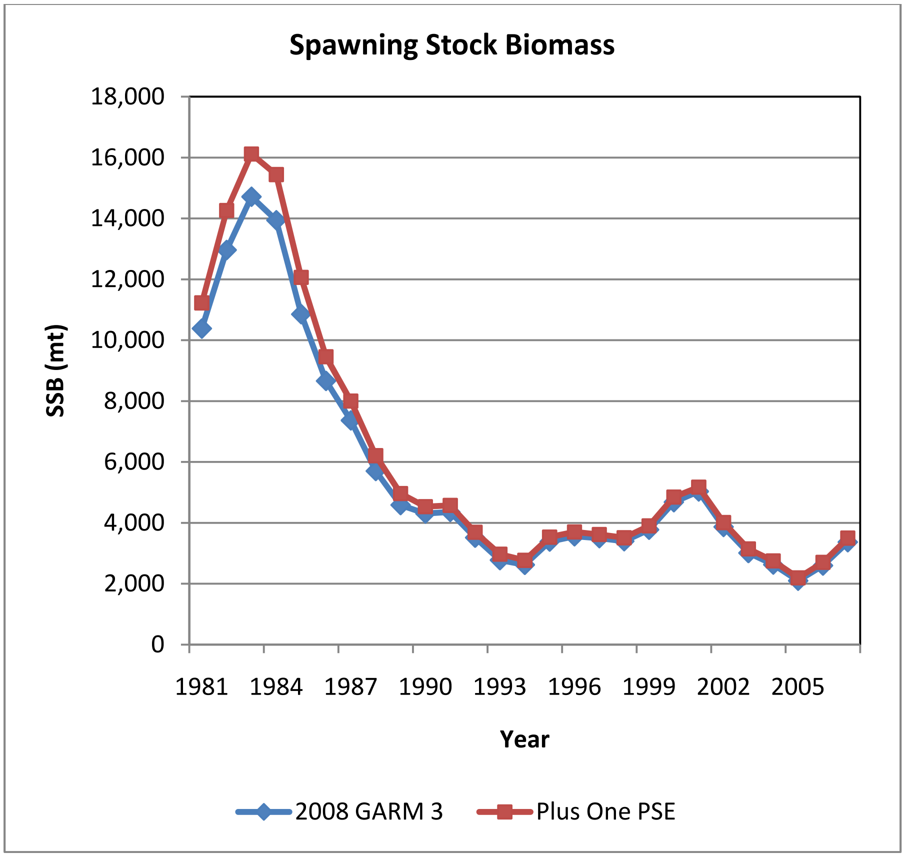

Figure 4.2. Comparison of SSB (mt) estimates from the 2008 GARM 3 assessment model and the Plus-One-PSE model run.

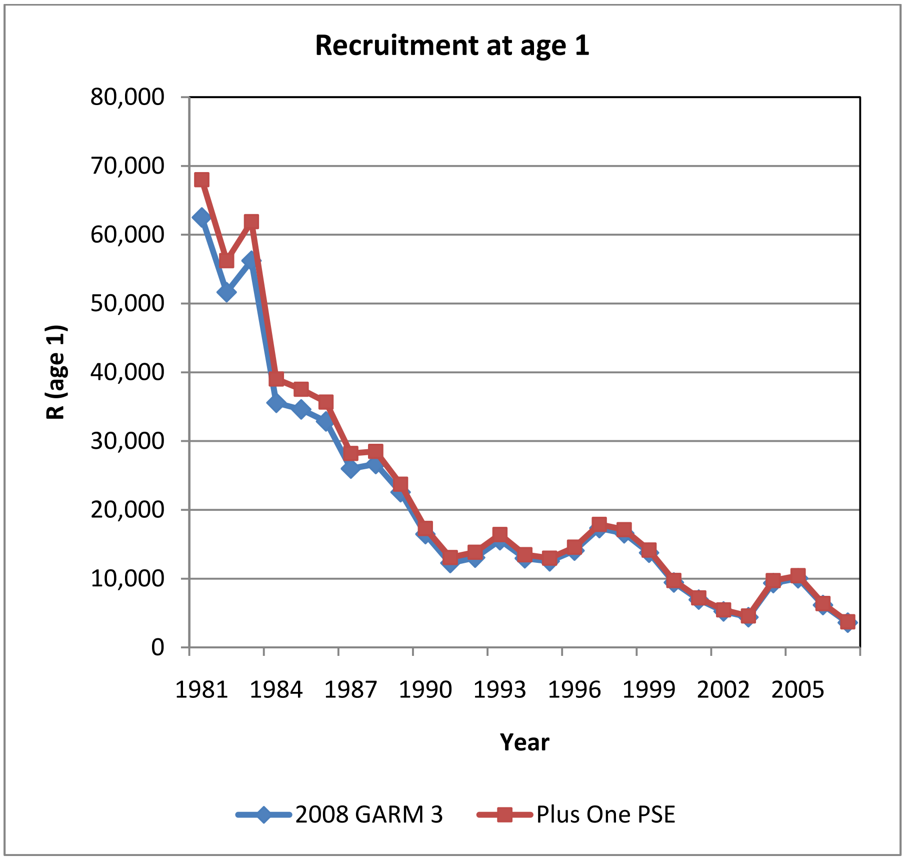

Figure 4.3. Comparison of Recruitment (R, thousands of age 1 fish) estimates from the 2008 GARM 3 assessment model and the Plus-One-PSE model run

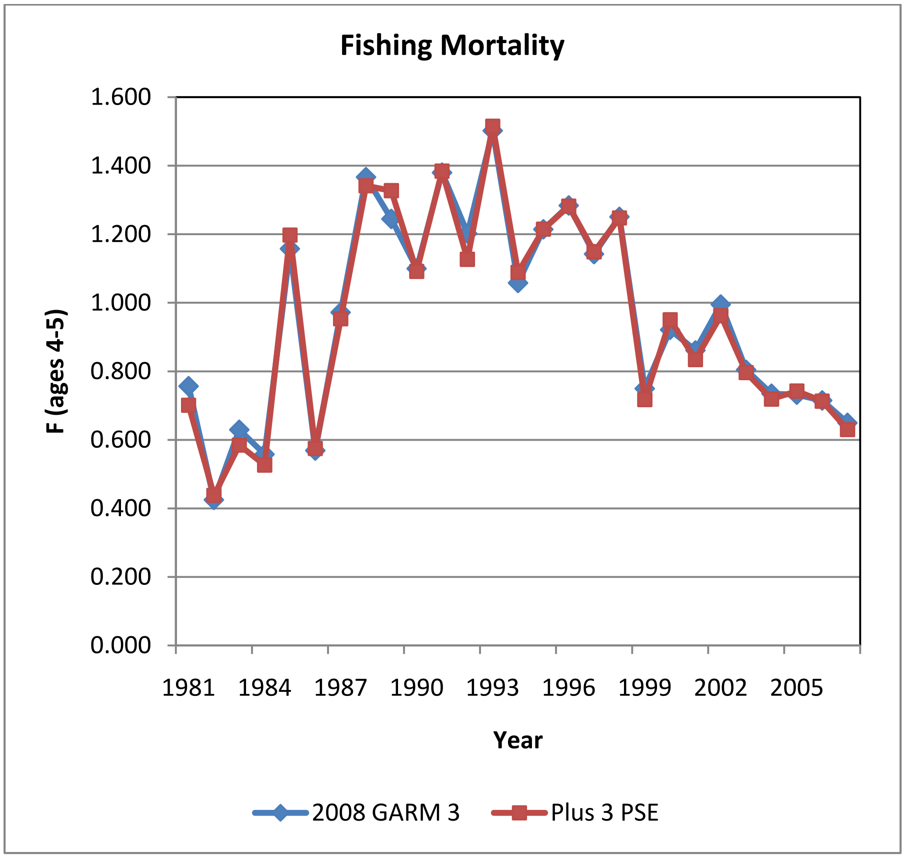

Figure 4.4. Comparison of fishing mortality rate (F ages 4-5) estimates from the 2008 GARM 3 assessment model and the Plus-3-PSE model run.

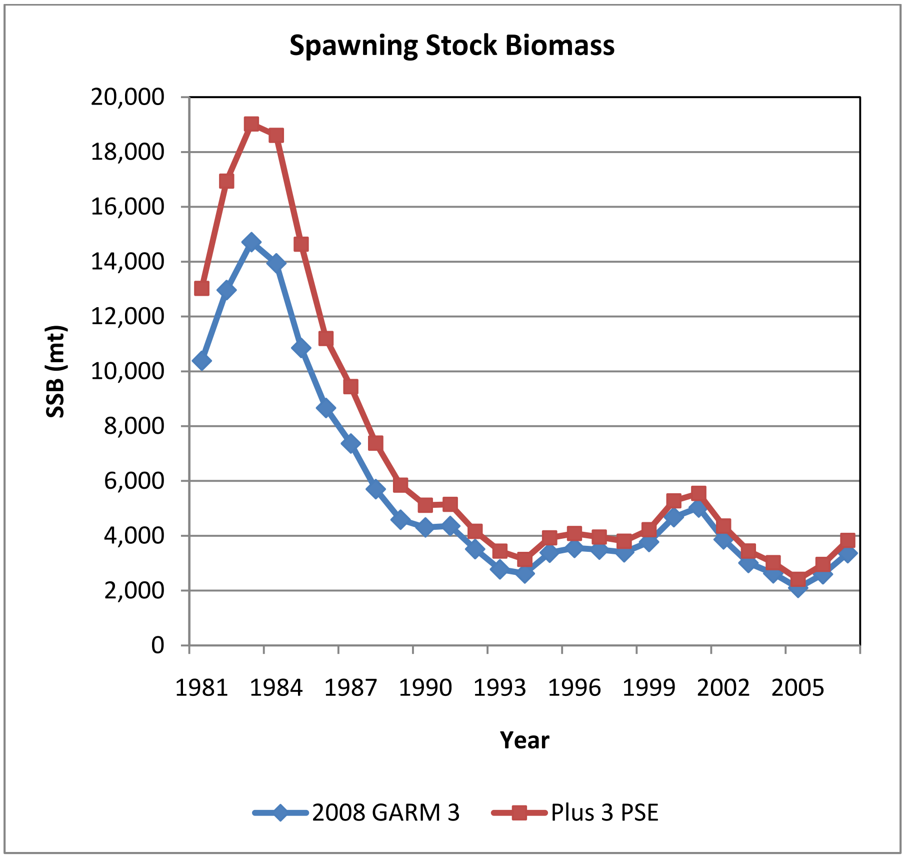

Figure 4.5. Comparison of SSB (mt) estimates from the 2008 GARM 3 assessment model and the Plus-3-PSE model run.

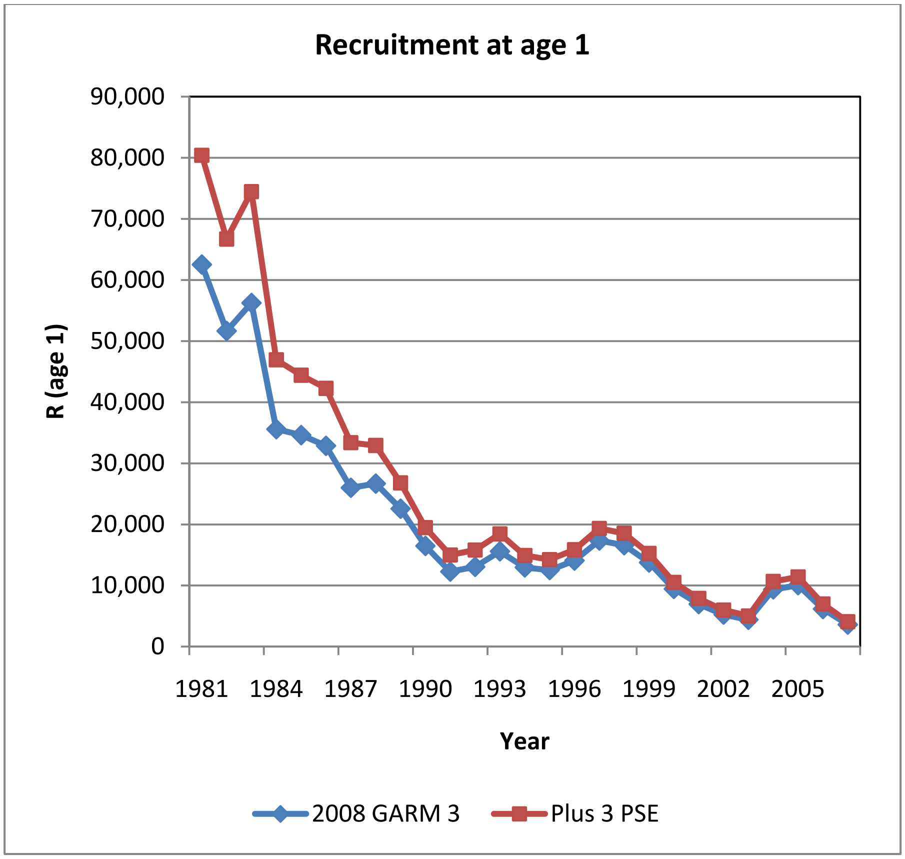

Figure 4.6. Comparison of Recruitment (R, thousands of age 1 fish) estimates from the 2008 GARM 3 assessment model and the Plus-3-PSE model run.

SDWG Background WP# 6
May 2011
Management Regulations

2001
January 9 – March 17 April 16 – April 30 Northern Shrimp season (61 days)
November 6: Daily haddock possession limit removed (maximum 50,000 lbs.-trip).
2002
February 15-March 11: Northern Shrimp season (25 days with days off)
May 1: Interim rule as a result of FW 33 lawsuit settlement agreement. Continuation of most measures from previous frameworks. DAS: 15 hour minimum charged for all trips over 3 hours Vessels limited to 25 percent of allocation May 1 through July 31, 2002 (only) Prohibition on front-loading DAS Minimum size: Cod 22 in. Gear: GOM Regulated Mesh Area (RMA): 6.5 in. diamond or square codend minimum, 6.5 inch mesh for trip gillnets, 6.5 inch mesh standup (roundfish) or 7 inch mesh tiedown (flatfish) for day gillnets. All areas: day gillnets limited to 50 standup/100 tiedown nets. *Hook gear*: de-hooking devices with spacing of less than six inches prohibited. Closures: WGOM year round closure extended (was to sunset May 1); Cashes Ledge Closed Area (year round); year round Cashes Ledge East and West closure added; add blocks 124/125 May, blocks 132/133 June, Recreational: Cod minimum size 23 in., GOM party/charter limited to 10 fish combined cod/haddock, all areas private recreational limited to 10 cod Possession limits: Remain the same. Haddock possession limit of 3,000 lbs.-DAS/30,000 lbs.-trip through September 30.
June 1: Revised interim rule Minimum size: Cod 19 in. Closures: Year-round Cashes Ledge east and west closures removed Gear: *Hook*: Requirement for six-inch spacing for de-hooking gear removed
July 4: Haddock daily limit suspended. Possession limit of 30,000 lbs.-trip until September 30, 50,000 lbs.-trip thereafter.
August 1: Emergency rule implementing FW 33 lawsuit settlement agreement. DAS: DAS allocation for each permit reduced 20 percent from maximum used FY 1996-2000 (est 71,218 allocated, including carry-over). DAS counted by the minute, except for day gillnet vessels (15 hour minimum). (This change reverted to DAS counting in effect in FY 2001). Prohibition on front-loading DAS clock. Minimum size: Cod 22 in. Gear: *Trawl:* GOM/GB RMAs: 6.5 in. diamond or square codend minimum; Southern New England RMA changed to 70W to 74W (vice 72-30W). 6.5 in. square, 7 in. diamond codend in SNE RMA. *Gillnet:* GOM: Trip gillnets – 6.5 in. mesh/150 nets; Day – 6.5 in./50 standup nets, 7 in./100 tiedown nets (prohibited March-June); GB – 6.5 in./50 nets, SNE – 6.5 in./75 nets; Mid-Atlantic: Trip – 5.5 in. diamond/6 in. square, Day – 5.5 in. diamond/6 in. square. *Hook*: no de-hookers with less than 6 in/. spacing, 12/0 circle hooks or larger; GOM: 2,000 rigged hooks, GB: 3,600 rigged hooks Closures: Add GB seasonal closure areas, May – Blocks 80, 81, 118, 119, 120 (south of 42-20N) Possession limits: *Yellowtail flounder*: SNE/MA: landing/possession of yellowtail flounder prohibited south of 40N. Mar 1 – May 31: 250 lbs./trip, June 1 – February 28: 500 lbs.-

DAS/4,000 lbs. – trip. *Cod*: GOM: 500 lbs.-DAS/4,000 lbs./trip. Open access commercial permits limited to 200 lbs. regulated groundfish. Recreational: Cod/haddock: 23 in. minimum size. Party/charter: GOM RMA: April-November, 10 cod/haddock combined per person, Dec-Mar – 10 cod/haddock combined, no more than 5 cod per person per trip. Private: GOM RMA: December-March – 10 cod/haddock combined, no more than 5 cod.
2003
January 15-February 27: Northern Shrimp season (38 days with days off)
March 13: Haddock possession limit suspended until May 1.
May 1: Haddock possession limit of 3,000 lbs-DAS/30,000 lbs.-trip
May 1: Framework Adjustment 37 Modifications to whiting management measures: extension of Cultivator Shoal whiting fishery by one month (June 15-October 31), changes to default measures, minor changes to Cape Cod Bay Raised Footrope Trawl exemption area.
May 13: Haddock possession limit revised to 30,000 lbs./trip (no daily limit).
July 9: Framework Adjustment 38 Raised footrope trawl whiting fishery in the inshore GOM, July 1 – November 30 each year.
July 28: Final emergency rule implementing FW 33 lawsuit settlement agreement Recreational: Haddock, 21 in. minimum size. Party/charter: GOM: Apr-Nov, 10 cod per person, December-March, 5 cod per person. Private: GOM: December-March, 10 cod/haddock combined, no more than 5 cod. Other areas: 10 cod/haddock combined.
October 7: Haddock possession limit suspended for the remainder of the fishing year.
2004
January 19-March 12: Northern Shrimp season (40 days with days off)
May 1: Implementation of Amendment 13. Measures based on emergency rule and measures in effect prior to interim rule. DAS: DAS for each permit re-categorized. Category 1: 60% of maximum DAS used FY 1996-2001 in years that permit landed 5,000 pounds regulated groundfish (est. 43,000 allocated). Category B: 40% of maximum DAS used FY 1996-2001 in years that permit landed 5,000 pounds regulated groundfish; can only be used in specific programs. DAS leasing and transfer programs allow DAS exchanges between vessels under limited conditions. (200 lbs. of winter flounder can be retained by vessels fishing for fluke west of 72-30 W without using a DAS). Minimum Size: No change from emergency rule (commercial); 22 inch cod, 19 inch haddock (rec) Gear**:** *Trawl*: No change from emergency rule. *Gillnet*: GOM/GB: Day-6.5 in./50 standup nets, no seasonal restriction on tie-down nets; Trip: 6.5 in. mesh/150 nets. SNE/MA: 6.5 in. in. mesh/75 nets. *Hook: GOM:* 2,000 hooks. *GB*: 3,600 hooks Closures: Same as emergency rule, with addition of habitat closed areas; all except Jeffrey Bank and NLCA habitat closed area are within existing year-round closed areas. Possession limits: *GOM cod*: 800 lbs-DAS/4,000 lbs.-trip. GB cod: 1,000 lbs.-DAS/10,000 lbs.-trip. *CC/GOM yellowtail flounder*: April, May, October, November - 250 lbs. trip, other months 750 lbs.-DAS/3,000 lbs-trip. *SNE/MA yellowtail flounder*: March –June, 250 lbs. trip, other months 750 lbs.-DAS/3,000 lbs-trip. *Haddock*: 3,000 lbs.-DAS/30,000 lbs.-trip. Special Management Programs: *US/Canada Area*: hard TAC on cod, haddock (SAs 561, 562), yellowtail flounder (SAs 522, 525, 561, 562). Cod possession limit: 500 lbs-DAS/5,000 lbs-trip, not more than 5 percent of catch. No DAS charged to/from SAs 561, 562. Exempted Fisheries: Northern Shrimp fishery area restriction removed; General Category scallop fishery exemption in SAs 537, 538, 539, and 613.
May 14: Haddock possession limit suspended for remainder of the fishing year.
June 1: CAII Yellowtail Flounder Special Access Program Access to CAII south of 41-30N by trawl vessels targeting yellowtail flounder. Limited to 320 trips (total), two trips per vessel per month, yellowtail flounder limited to 30,000 lbs./trip. Authorized use of Category B DAS.

June 23: Amendment 10 to the Atlantic Sea Scallop FMP. 10-in. square mesh twine top required for all scallop dredge vessels in all areas.
September 3: CAII Yellowtail Flounder SAP ends (no trips can begin after this date)
November 2: Framework Adjustment 39 (Scallop Framework Adjustment 16) Scallop dredge vessel access to portions of groundfish mortality CAII and NLCA in 2004, CAI and CAII in 2005, and CAI and NLCA in 2006. Season: June 15 through January 31. Possession limits: 1,000 lbs. regulated groundfish, no more than 100 lbs. cod. In NLCA, limited to 250 lbs.-trip yellowtail flounder in June. (Outside of access program, scallop vessels continue to be limited to 300 lbs. regulated groundfish per trip). Yellowtail flounder catch capped at 10 percent of target TAC for the stock.
October 1: Closure of SAs 561 and 562 to all fishing on a multispecies DAS. Prohibition on the possession of yellowtail flounder from SAs 522, 525, 561, 562.
November 19: Framework Adjustment 40A *Closed Area I Haddock SAP* Access to small area of CAI to target haddock using longlines. Limited to 1,000 mt haddock TAC. Season ends December 31. *Eastern US/CA Area Haddock SAP Pilot Program* Access to northern corner of CAII and adjacent area to target haddock using separator trawl. Season: May 1 through December 31. Authorized use of Category B DAS. *Category B (regular) DAS Pilot Program* Vessels can use Category B (regular) DAS to target healthy stocks. Catch (kept and discarded) limited to 100 lbs. of cod, American plaice, white hake, witch flounder, ocean pout, SNE/MA winter flounder and windowpane flounder, 25 lbs.-DAS/250 lbs.-trip of yellowtail flounder. Maximum of 1,000 DAS can be used in each of four quarters from November 1, 2004 through October 31, 2005.
2005
January 14: Eastern US/CA reopened, yellowtail flounder daily poundage limit lifter (maximum remains 15,000 lbs./trip). Cod trip limit of 5,000 lbs./trip in Eastern US/CA area. Vessels fishing in Eastern US/CA area must use haddock separator trawl.
February 9: GB yellowtail flounder trip limit reduced to 5,000 lbs./trip in (entire) US/CA Management Area.
April 1: Eastern US/CA area closed until April 30, 2005, possession of GB yellowtail flounder prohibited in entire US/CA Management Area.
May 1: Eastern US/CA Area reopens at beginning of fishing year. Measures revert to those implemented May 1, 2004.
May 3: Haddock trip limit removed for remainder of the fishing year.
May 26: FW 40B implemented. Changes DAS leasing and transfer program, modifies GB Hook Sector provisions, adopts reporting requirements for herring vessels, modifies trip gillnet provisions. *CAII Yellowtail Flounder SAP* Changes starting date to July 1, reduces trip limit to 10,000 lbs, number of trips per vessel per month is one, process established for adjusting the total number of trips.
June 8: Emergency action to control bycatch of haddock in the herring fishery establishes trip limit and overall TAC.
June 15: Implementation of FW 16 to the Sea Scallop FMP authorizes General Category Scallop vessel participation in scallop access areas. Scallop access areas in CAI and CAII open for all vessels on this date.
June 27: Announcement that no trips will be allowed in the CAII Yellowtail Flounder SAP in FY 2005.
July 12: NE multispecies DAS vessels are limited to one trip per month in the Eastern US/CA area.
July 18: Multispecies DAS vessels are prohibited from fishing in the Category B (regular) DAS program in the GB cod stock area through July 31.
July 27: NE multispecies trawl vessels are required to use a haddock separator trawl when fishing in the Eastern US/CA area.
August 26: Eastern US/CA area is closed to all limited access multispecies DAS vessels because 90

percent of the GB cod TAC for the area is projected to be harvested.
September 6: CAI scallop access area is closed to General Category scallop vessels.
September 13: *CAI Hook Gear Haddock SAP* FW 41 to the Northeast Multispecies FMP implemented. This action allows non-sector longline vessels to participate in the CAI Hook Gear Haddock SAP. The October 1 – December 31 season is divided in half, with sector vessels fishing in the first half and non-sector vessels in the second.
October 6: Participation in the Category B (regular) DAS Pilot Program is prohibited because the quarterly allocation of 1,000 DAS is used. The program ends for FY 2005.
October 31: Boundaries of the sea scallop access areas within CAI and the NLCA access areas are adjusted.
December 12: Northern shrimp fishery opens and will remain open through April 30, 2006.
December 21: The trip limit for NE multispecies vessels fishing for GB yellowtail flounder is changed from unlimited to 15,000 lbs per trip. The quota for the second period of the CAI Hook Gear Haddock SAP is increased to 536.6 mt.
2006
January 12: The emergency rule allowing Atlantic herring vessels to possess haddock is extended for an additional 180 days.
January 31: Areas within groundfish closed areas that are open to scallop fishing through the scallop access area program close at midnight.
February 7: The trip limit for NE multispecies vessels fishing for GB yellowtail flounder is reduced to 1,500 lbs. per DAS up to a maximum of 15,000 lbs.
February 22: The trip limit for NE multispecies vessels fishing for GB yellowtail flounder is changed to 15,000 lbs. per trip regardless of trip length.
March 24: The trip limit for NE multispecies vessels fishing for GB yellowtail flounder is increased to an unlimited amount regardless of trip length.
April 30: Northern shrimp fishery season closes at midnight.
May 1: Implementation of an emergency rule to reduce fishing mortality on groundfish stocks while FW 42 is reviewed. Revised regulations are: DAS: DAS charged at the differential rate of 1.4:1 for all areas outside the US/CA area. Minimum Size: No changes for commercial vessels. Gear**:** No changes. Closures: No changes Possession limits: *GOM cod*: 600 lbs-DAS/4,000 lbs.-trip. *GB cod*: 1,000 lbs.-DAS/10,000 lbs.-trip outside of eastern US/CA area. *CC/GOM yellowtail flounder*: May, June October, November - 250 lbs. trip, other months 500 lbs.-DAS/2,000 lbs-trip. *GB yellowtail flounder*: 10,000 lbs. per trip; *GB winter flounder*: 5,000 lbs. per trip; *SNE/MA yellowtail flounder*: March –June, 250 lbs. trip, other months 750 lbs.-DAS/3,000 lbs-trip. White hake: 1,000 lbs.-DAS/10,000 lbs.-trip. *Haddock*: Trip limit removed for duration of emergency action. Special Management Programs: ***Eastern*** *US/Canada* ***haddock SAP***: Opening delayed until August 1. Category B (regular) DAS Program: Renewed, with vessels restricted to the US/CA Area, required to use a haddock separator trawl, limited to 500 days May-June, 1,000 days in other quarters, low trip limits on stocks of concern. Recreational measures: Possession of GOM cod prohibited from November 1 – March 31. Minimum size for GOM cod increased to 24 in. Other: Vessels allowed to fish inside and outside the eastern US/CA area on the same trip.
May 19: Announcement that CAII Yellowtail SAP will not open due to low TAC.
June 19: All trawl vessels fishing in the eastern US/CA area required to use a haddock separator trawl.
July 12: General category scallop vessel access to Nantucket Lightship Close area closed due to catching yellowtail flounder incidental catch TAC.
July 20: Limited access scallop vessel access to Nantucket Lightship Close area closed due to catching yellowtail flounder incidental catch TAC.
August 11: FW 43 implemented; addresses incidental catch of regulated multispecies by herring

vessels. Haddock possession by midwater trawl vessels is allowed subject to a TAC.
September 6: Scallop vessel access to CAII closed due to yellowtail flounder bycatch.
October 1: CAI Hook Gear Haddock SAP opens.
November 22: Implementation of FW 42. Major regulatory changes: DAS: DAS charged at the differential rate of 2:1 for an area in the inshore GOM (for an entire trip if any part of the trip fished in the area) and an area in SNE (only time fishing in the area). Minimum Size: No changes for commercial vessels. Gear**:** No changes. Closures: No changes Possession limits: *GOM cod*: 800 lbs-DAS/4,000 lbs.-trip. *CC/GOM yellowtail flounder*: 250 lbs-DAS/1000 lbs. per trip. *SNE/MA yellowtail flounder*: 250 lbs-DAS/1000 lbs. per trip. Haddock trip limit unlimited. ***GB Yellowtail flounder: 10,000 lbs/trip. White Hake: 500 lbs-DAS/5,000 lbs-trip (this was an error – FW 42 says 1,000/10,000 per trip).*** Special Management Programs: *US/Canada Area*: Opening delayed until August 1. Prohibition on discarding legal sized fish. Category B (regular) DAS Program: Renewed for all areas. Trawl vessels required to use a haddock separator trawl, limited to 500 days May-June, 1,000 days in other quarters, low trip limits on stocks of concern. Prohibition on discarding legal sized fish. Recreational measures: (same as emergency rule) Possession of GOM cod prohibited from November 1 – March 31. Minimum size for GOM cod increased to 24 in. Other: (same as emergency rule) Vessels allowed to fish inside and outside the eastern US/CA area on the same trip.
December 1: Northern shrimp fishery opens: 151 days, seven days per week.
2007
March 5: Trawl vessels fishing in the eastern US/CA area allowed to use either a haddock separator trawl or a flounder net. GB yellowtail flounder trip limit reduced to 5,000 lbs.-trip for all vessels declaring into the eastern US/CA area.
April 5: Trip limit for GB yellowtail flounder increased to 25,000 lbs.-trip for the entire US/CA area for the remainder of the fishing year (through April 30).
April 25: Eastern U.S./Canada area closed to limited access multispecies vessels (through April 30, 2007).
April 30: Northern shrimp fishery closed at midnight.
May 1: Enforcement protocol for measuring nets changes. For mesh over 4.72 inches (120 mm), weight used with net spade increased to 8 kg (from 5 kg). Eastern U.S./Canada area reopens. No trips are authorized in the CAII yellowtail flounder SAP in 2007. Trip limit for GB yellowtail flounder reduced to 3,000 pounds per trip in the U.S./Canada area. Interim measures adopted for monkfish FMP restrict monkfish trip limits, reduce DAS that can be used in the SFMA, and does not allow carryover of monkfish DAS.
June 15: NLCA and CAI scallop access areas open.
June 20: Eastern US/CA area is closed to limited access multispecies DAS vessels due to cod catch.
July 8: The NLCA scallop access area is closed to General Category Scallop vessels.
July 15: The CAI scallop access area is closed to General Category Scallop vessels.
August 3: NMFS modifies permit renewal requirements for limited access multispecies vessels. Changes limit ability of vessels to fish in state waters outside of the FMP and retain eligibility for a federal limited access permit.
August 9: Minimum size for GB and GOM haddock caught by commercial vessels is reduced to 18 inches. Minimum size for all recreational vessels remains at 19 inches.
October 1: CAI Hook Gear Haddock SAP opens for GB Cod Hook Sector vessels.
October 20: The Eastern US/CA area is opened to limited access multispecies DAS vessels. The GB cod possession limit is 1,000 lb/trip for all vessels declared into the Eastern US/CA Area or the Eastern US/CA Area SAP.
November 15: CAI Hook Gear Haddock SAP opens for non-sector vessels.

November 27: GB yellowtail flounder trip limit for vessels fishing in the US/CA management area increased to 7,500 lb/trip.
November 30: Eastern US/CA area closes
December 1: Northern Shrimp fishery opens. Season scheduled for 152 days, seven days per week.
December 11: CAI Hook Gear haddock SAP second period haddock quota increased to 4,789 mt.
2008
January 10: GB yellowtail flounder tip limit in the U.S/Canada management area set at 1,500 lbs./trip
January 24: Harvesting, possessing, and landing GB yellowtail flounder from the entire U.S./Canada management area is prohibited through April 30, 2008 (applies to trips that have not begun prior to announcement).
February 6: Minimum size for both GB and GOM haddock remains at 18 inches total length; extended through August 10, 2008.
March 12: Scallop elephant trunk access area closed to General Category scallop vessels.
April 30: Northern shrimp fishery closes.
May 1: GB yellowtail flounder trip limit set at 5,000 lbs./trip Eastern U.S./Canada area opening delayed until August 1, 2008 for vessels fishing with trawl gear. Eastern U.S./Canada area opened to longline gear but with a cod cap of 33.4 mt.
May 30: CAII yellowtail SAP remains closed (no trips authorized for FY 2008).
August 1: GOM and GB haddock minimum size reverts to 19 inches. Eastern U.S./Canada management area opens to all vessels. U.S./Canada Haddock SAP opens.
August 4: Happy Birthday, U.S. Coast Guard. The Nantucket Lightship Closed Area closed to scallop vessels to prevent exceeding the yellowtail flounder incidental catch cap.
August 13: Haddock rope trawl (later called the Ruhle trawl, previously called the eliminator trawl) approved for use in the Category B (regular) DAS program and the U.S./Canada Haddock SAP.
September 15: Ruhle trawl authorized for use in the Eastern U.S./Canada management area.
October 1: CAI Hook Gear Haddock SAP opens for non-sector vessels.
October 23: GB yellowtail flounder trip limit reduced from 5,000 lbs./trip to 2,500 lbs./trip for vessels fishing in the U.S./Canada management area.
November 15: CAI Hook Gear Haddock SAP opens for GB cod hook sector vessels.
December 1: Northern shrimp fishery opens for 180 days, seven days per week. Closure scheduled for May 29, 2009.
December 23: Landing limit for Eastern GB cod increased to 1,000 lbs./DAS up to a maximum of 10,000 lbs./trip (applies to cod caught in the Eastern U.S./Canada management area).
December 30: Limited access General Category scallop fishery closed.
2009
January 26: NE Multispecies regulations adopted by FW 42 suspended as a result of a court order. No clear explanation of what measures are affected.
February 13: NMFS identifies following measures as NOT impacted by the court order to suspend measures adopted by FW 42: • Recordkeeping and reporting requirements • Gear restrictions • DAS allocations • Time and area closures • Minimum fish sizes • SAPs • Recreational measures • Cape Cod Hook Sector • Some possession limits (GOM cod 800 lbs DAS-4,000 lbs/trip,, GB cod 1,000 lbs./DAS – 10,000 lbs./trip, US/CA area trip limits Confusion continues on what regulations are not in effect.
February 17: Federal court rescinds decision to suspend FW 42 measures and limits suspension to differential DAS counting areas in the GOM and SNE/MA areas, and authorizes submission of DAS

leasing requests through March 31, 2009 (vice normal March 1 deadline for such requests).
March 9: Eastern GB cod landing limit reduced to 500 lbs./DAS – 5,000 lbs./trip. GB yellowtail flounder trip limit increased to 5,000 lbs/trip.
April 1: DELMARVA scallop access area closed to General Category scallop vessels.
April 16: Eastern US/CA area closed until May 1.
May 1: Interim rules in effect to reduce overfishing on multispecies stocks until Amendment 16 implemented. Major changes: DAS: DAS allocations reduced according to Amendment 13 schedule. Category A DAS are reduced to 45 percent of the permit's DAS baseline, an 18 percent reduction from the previous year's allocations. Differential DAS area increased in SNE/MA. Minimum Size: Haddock 18 inch minimum size. Gear**:** No changes. Closures: No changes Possession limits: *GOM cod*: 800 lbs-DAS/4,000 lbs.-trip. *GB cod*: 1,000 lbs./DAS-10,000 lbs./trip (eastern US/CA area 500 lbs./DAS-5,000 lbs./trip). *CC/GOM yellowtail flounder*: 250 lbs-DAS/1000 lbs. per trip. *SNE/MA yellowtail flounder*: 250 lbs-DAS/1000 lbs. per trip. Haddock trip limit unlimited. *GB Yellowtail flounder*: 5,000 lbs/trip. *White Hake*: 1000 lbs-DAS/10,000 per trip). GB winter flounder: 5,000 lbs./trip. Witch flounder: 1,000 lbs./DAS-5,000 lbs./trip. Possession *of ocean pout, northern windowpane flounder, and SNE/MA winter flounder* prohibited. Special Management Programs: *US/Canada Area*: Opening delayed until August 1 for trawl vessels. *SNE/MA winter flounder SAP* suspended. State waters winter flounder exemption eliminated. *CAI Hook Gear Haddock SAP* expanded to May 1 to January 31, area increased, no separation between common pool and sector participants. Recreational Measures: GB cod bag limit of n10 cod per person per day for party/charter vessels; retention of GOM cod prohibited from November through April 15; retention of SNE/MA winter flounder prohibited; haddock minimum size reduced to 18 inches. Other: Conservation tax removed from DAS transfers.
May 6: Limited access general category scallop fishery closed to IFQ vessels until June 1.
May 29: Northern shrimp fishery closes.
June 5: GB yellowtail flounder trip limit reduced to 2,500 lbs./trip
June 26: eastern US/CA Area closed to all vessels until August 1 (including fixed gear vessels) to prevent exceeding first quarter GB cod TAC.
June 29: CAII Scallop Access Area closed to prevent exceeding GB yellowtail flounder cap.
July 6: *GB winter flounder* trip limit removed. *White hake* trip limit increased to 2,000 lbs./DAS-10,000 lbs./trip.
July 19: Limited access general category scallop fishery closed to IFQ vessels until September 1.
September 15: Limited access general category scallop fishery closed to IFQ vessels until December 1.
September 17: Use of flounder trawl net prohibited when fishing in the Eastern US/CA area.
November 2: Mid-water trawl vessels fishing in CAI subject to 100 percent observer coverage, prohibition on releasing catch before sampling by observer.
November 20: In the US/CA management area, trawl vessels required to use a haddock separator trawl or Ruhle trawl south of 41-40N latitude. Any vessel fishing in this area and other areas cannot use any other gear on the same trip. Vessels fishing north of 41-40N for the entire trip can use any legal gear.
December 1: Northern shrimp fishery opens for 180 days; scheduled to close May 29, 2010.
2010
January 12: Limited access general category scallop fishery closed to IFQ scallop vessels
March 1: Limited access general category scallop IFQ program opens. Scallop fishery Elephant Trunk and DELMARVA Access Areas open.
March 11: All multispecies vessels fishing on a Category A DAS allowed to use any legal trawl gear in the Western US/CA Area (statistical areas 522, 525) (lifts restrictions adopted November 20, 2009).
April 13: All multispecies vessels fishing on a Category A DAS allowed to use a flounder trawl net in the Eastern US/CA area.

April 20: Eastern US/CA area (statistical areas 561, 562) closed to multispecies vessels and harvest, possession, and landing of GB yellowtail flounder from entire US/CA area (statistical areas 522, 525, 561, 562) prohibited.
May 1: Implementation of Amendment 16 and Framework 44. Expansion of sector management program to majority of the fishery. Major revisions to common pool measures for permitted vessels not in sectors. Adoption of additional at-sea and dockside monitoring requirements for sector vessels, and new reporting requirements for other vessels. Adoption of new US/CA area TACs. Adoption of annual catch limit (ACL) and accountability measures (AM) for most stocks. No retention of SNE/MA winter flounder, ocean pout, windowpane flounder, Atlantic wolffish. Specific allocations of GOM cod and GOM haddock made to the recreational and commercial groundfish fisheries. Key elements: *Sector Management:* Vessels in sectors subject to hard TACs for most stocks, increased at-sea monitoring (targeting 38 percent of trips), dockside monitoring; not subject to trip limits, some GOM rolling closures, groundfish DAS limits. Permits committed to sectors account for 94 percent or more of available catch except for GOM WFL (84 pct) and SNE/MA YTF (76 pct), and SNE/MA WFL (0%). Total permits committed to sectors: 762. Sector vessels required to retain all legal-sized fish (except limited to one Atlantic halibut, and the five species prohibited). Sectors required to stop fishing in a stock area when a quota (Annual Catch Entitlement, or ACE) for a stock in the area is caught. *Common pool*: Only a small portion of the ACL available to common pool vessels. Major elements of common pool regulations: DAS: Category A DAS allocations reduced to 27.5 percent of the Amendment 13 baseline allocation. All DAS charged in 24 hour increments. Minimum Size: Haddock 18 inch minimum size. Halibut size increased to 41 inches. Gear**:** No changes. Closures: No changes Possession limits: *GOM cod*: 800 lbs-DAS/4,000 lbs.-trip. *GB cod*: 2,000 lbs./DAS-20,000 lbs./trip (eastern US/CA area 500 lbs./DAS-5,000 lbs./trip). *Pollock*: 1,000 lbs./DAS – 10,000 lbs/trip; *CC/GOM yellowtail flounder*: 250 lbs-DAS/1500 lbs. per trip. *SNE/MA yellowtail flounder*: 250 lbs-DAS/1500 lbs. per trip. Haddock trip limit unlimited. *GB Yellowtail flounder*: 2,5000 lbs/trip offshore; 250 lbs./DAS-1,500 lbs./trip inshore. *White Hake*: 2,000 lbs-DAS/10,000 per trip). GB winter flounder: 5,000 lbs./trip. Witch flounder: 1,000 lbs./DAS-10,000 lbs./trip. GB winter flounder: Offshore 5,000 lb./trip. Possession *of ocean pout, windowpane flounder, Atlantic wollffish, and SNE/MA winter flounder* prohibited. Restricted Gear Areas: Areas near CAI and off SNE created to reduce flatfish catches; limited to separator/Ruhle trawls, rope trawl, certain gillnets in these areas. Limited to 500 lbs. of flatfish combined in these areas. Special Management Programs: *US/Canada Area*: Opening delayed until August 1 for trawl vessels. Prohibition on discarding legal sized fish. *SNE/MA winter flounder SAP* suspended. State waters winter flounder exemption eliminated. *CAI Hook Gear Haddock SAP* expanded to January 31, area increased, no separation between common pool and sector participants. *CAII yellowtail flounder –haddock SAP*: SAP opening authorized to target haddock (not GB yellowtail flounder_ subject to specific gear requirements. Opening date August 1. *Adjustments*: RA authorized to make in-season adjustments to trip limits and DAS counting rates. *DAS Leasing and Transfers:* Permits in CPH category allowed to participate in these programs. No conservation tax on transfers. Recreational Measures: GOM cod bag limit of 10 cod per person per day for party/charter vessels; 10 fish bag limit on all cod for private vessels; retention of GOM cod prohibited from November through April 15; retention of SNE/MA winter flounder prohibited; Atlantic wolffish retention prohibited; haddock minimum size reduced to 18 inches. Halibut size increased to 41 inches. No limit on hooks (two hook limit removed).
May 5: Northern shrimp fishery season closes
May 27: Changes to common pool trip limits: GOM haddock: 1,000 lbs./trip

GB haddock: 10,000 lbs./trip GOM winter flounder: 250 lbs./trip GB winter flounder: 1,000 lbs./trip (offshore) GB yellowtail flounder: 1,000 lbs./trip (offshore)
June 28: NLCA scallop access area opens
July 15: Pollock ACL revised; increased to 16,553 mt.
July 30: Changes to common pool measures: GB yellowtail flounder: Selective trawl gear required in Eastern US/CA area and Western US/CA area south of 41-40N. GOM cod: 200 lbs./DAS-1,000 lbs./trip
August 6: Changes to common pool measures: Pollock trip limit removed Witch flounder: 130 lbs./trip
August 31: Common pool DAS counting rate set to 2:1 for GOM and GB differential DAS areas.
September 22: Changes to common pool measures: GOM cod: 100 lbs./DAS-1,000 lbs./trip GB yellowtail flounder: 100 lbs./trip White hake: 100 lbs./DAS – 500 lbs./trip US/CA area: Selective trawl gear required to entire US/CA management area
October 18: Handgear A cod trip limit reduced to 50 lbs/trip.
December 1: Northern shrimp season opens

Winter Flounder Length-based Survey Calibration

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September 10, 2011

Introduction

In 2009, the *NOAA SHIP Henry B. Bigelow* replaced the *R/V Albatross IV* as the primary vessel for conducting spring and fall annual bottom trawl surveys for the Northeast Fisheries Science Center (NEFSC). There are many differences in the vessel operation, gear, and towing procedures between the new and old research platforms (NEFSC Vessel Calibration Working Group 2007). To merge survey information collected in 2009 onward with that collected previously, we need to be able to transform indices (perhaps at size and age) of abundance from the *Henry B. Bigelow* into those that would have been observed had the *Albatross IV* still been in service. The general method for merging information from these two time series is to calibrate the new information to that of the old (e.g., Pelletier 1998, Lewy et al. 2004, Cadigan and Dowden 2010). Specifically we need to predict the relative abundance that would have been observed by the *Albatross IV* ($\hat{R}_A$) using the relative abundance from the *Henry B. Bigelow* (R_B) and a "calibration factor" (ρ),

$$\hat{R}_A = \rho R_B . \tag{1}$$

To provide information from which to estimate calibration factors for a broad range of species, 636 paired tows were conducted with the two vessels during 2008. Paired tows occurred at many stations in both the spring and fall surveys. Paired tows were also conducted during the summer and fall at non-random stations to augment the number of non-zero observations for some species. Protocols for the paired tows are described in NEFSC Vessel Calibration Working Group (2007).

The methodology for estimating the calibration factors was proposed by the NEFSC and reviewed by a panel of independent scientists in 2009. The reviewers considered calibration factors that could potentially be specific to either the spring or fall survey (Miller et al. 2010). They recommended using a calibration factor estimator based on a beta-binomial model for the data collected at each station for most species, but also recommended using a ratio-type estimator under certain circumstances and not attempting to estimate calibration factors for species that were not well sampled.

Since the review, it has become apparent that accounting for size of individuals can be necessary for many species. When there are different selectivity patterns for the two vessels, the ratio of the fractions of available fish taken by the two gears varies with size. Under these circumstances, the estimated calibration factor that ignores size reflects an average ratio weighted across sizes where the weights of each size class are at least in part related to the number of individuals at that size available to the two gears and the number of stations where individuals at that size were caught. Applying calibration factors that ignore real size effects to surveys conducted in subsequent years when the size composition of the available population is unchanged should not produce biased predictions (eq. 1). However, when the size composition changes, the frequency of individuals and number of stations where individuals are observed at each size changes and the implicit weighting across size classes used to obtain the estimated calibration factor will not be applicable to the new data. Consequently, the predictions from the constant calibration factor of the numbers per tow that would have been caught by the *Albatross IV* will be biased.

Length-based calibration has been performed for groundfish (cod, haddock, and yellowtail flounder through the Trans-boundary Resource Assessment Committee process and silver, offshore, and red hakes during SARC 51 and loligo squid during SARC 51 (Brooks et al. 2010, NEFSC 2011). For those length-based calibrations, the same basic beta-binomial model from Miller et al. (2010) was assumed, but various functional forms were assumed for the relationship of length to the calibration factor. Since then, Miller (submitted) has explored two types of smoothers for the relationship of relative catch efficiency to length and the beta-binomial dispersion parameter. The smoothers (orthogonal polynomials and thin-plate regression splines) allow much more flexibility than the functional forms previously considered for other species by Brooks et al. (2010) and NEFSC (2011). Catch efficiency at length, $q(L)$, as defined here relates the expected catch to the density of available individuals on a per unit swept area basis,

$$E\left(C_{ik}\left(L\right)\right) = q_k\left(L\right) f_{ik} A_{ik} D_i\left(L\right)$$

where $D_i\left(L\right)$ is the density of available fish at station i, and f_{ik} and A_{ik} are the fraction of the catch sampled for lengths and swept area for vessel/gear k. Relative catch efficiency is the ratio of the catch efficiencies for two vessels and is related to the calibration factor,

$$\rho\left(L\right) = \frac{E\left(C_{i1}\left(L\right)\right)}{E\left(C_{i2}\left(L\right)\right)} = \frac{q_1\left(L\right)}{q_2\left(L\right)} \frac{f_{i1} A_{i1}}{f_{i2} A_{i2}}.$$

Miller (submitted) analyzed data for six species including winter flounder and the Skate Plan Development Team of the New England Fisheries Management Council has explored these methods to estimate smoother-based calibration factors for the complex of six skate species.

For SARC 52, the Working Group reviewed the work by Miller (submitted) on winter flounder in greater detail. The working group also decided to compare these results to those from another model that accounted for effects of stock area (Gulf of Maine, Georges Bank, and southern New England). The Working Group was also interested in seasonal effects, but chose not to pursue these models due to a lack of samples in the Gulf of Maine stock area during the spring survey. The lead assessment scientists for each of the winter flounder stocks also compared predicted indices in Albatross units based on the different the fitted models to check for any disparities (see their respective working documents for these comparisons).

Methods

The data used in to fit the winter flounder calibration models are numbers sampled by vessel, station, and 1 cm length class. I considered the same classes of smoothers as Miller (submitted) and the way stock areas are attributed to the calibration data are defined in Table 1. I used the model with the second best AIC_C value from Miller (submitted) rather than that with the best value as a starting point because the predicted relative catch efficiencies were virtually identical and the chosen model was substantially more parsimonious, particularly for the dispersion portion of the beta-binomial model. The chosen model assumes fourth order orthogonal polynomial smoother of the effects of length on the calibration factor and effects of area swept (A_{ik}) and sampling fraction (f_{ik}) of each vessel on the beta-binomial dispersion parameter. I accounted for stock area effects by allowing all parameters to differ by stock area (i.e., interactions of stock area with length, sampling fraction, and swept area covariates were included). I compared relative goodness-of-fit of the models using Akaike Information Criteria corrected for small sample size bias (AIC_C; Hurvich and Tsai 1989). I fit models in the R statistical programming environment (R Development Core Team 2010) and used the GAMLSSS package (Rigby and Stasinopoulos 2005, Stasinopoulos and Rigby 2007).

Results and Discussion

When fitting the fourth order polynomial models to data from each region, there were convergence issues for the Gulf of Maine likely due to over-parameterization of the length effects. When the order of the polynomial was reduced to two for this region, these issues were resolved. The resulting model performed better than the best models Miller (submitted) fit that did not account for effects of stock area (Table 2). Inspection of residuals reveals no strong trend with predicted number captured by the Henry B. Bigelow or total number captured by station and no strong departure from normality (Figure 1). The predicted relative catch efficiency was lowest at intermediate size classes for all three stock areas, but the location of the minimum was at larger size for the Georges Bank than the other stock areas. For southern New England, there were actually two minima with a slight rise in relative catch efficiency estimated between them.

When applying the relative catch efficiencies to surveys conducted in 2009 and 2010 with the *Henry B. Bigelow*, there is an important caution to note. Lengths may be observed in these surveys that are outside of the range of lengths observed during the calibration study. This problem is exacerbated when the data are broken down into stock area subsets for estimation of relative catch efficiency because the limits of the range of sizes available in the subsets can be narrower than the range of the entire data set (see Table 3). Caution must be taken in predicting catches in *Albatross IV* units at these sizes. The working group had some concern with the asymptotically increasing estimates of relative catch efficiencies at the smallest and largest sizes for the winter flounder stocks, particularly if converting historic Albatross indices to Bigelow equivalents were attempted. Sizes of fish outside of the ranges observed during the calibration study would potentially lead to extremely high Bigelow abundance indices at the extremes of the length composition for the historic data. An adaptation of the regional model was briefly explored that constrained lengths beyond a minimum and maximum length to have constant relative catch efficiencies. The minima and maxima were determined by specifying a maximum coefficient of variation (CV) of predicted relative catch efficiencies at these lengths. These CV criteria resulted in models that provided aggregate abundance indices that were very similar to the corresponding models without the CV criteria. Because no ad-hoc CV criteria were necessary in the initial models, the working group found these to be preferable.

Lastly, the swept areas for tows during the 2009 and 2010 surveys would ideally be used to predict Albatross catches at each station, but if there is little variability in the swept areas a mean can be used and the mean number per tow at length in *Henry B. Bigelow* “units” can be converted to *Albatross IV* units (Table 4).

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Table 1. NEFSC survey strata used for Gulf of Maine, Georges Bank and southern New England stock areas in length-based calibration analyses. Note that these may not be identical to those used for assessment indices.

Gulf of Maine	Georges Bank	Southern New England
01260-01270	01130-01240	01010-01120
01330-01340		01250
01351		01690-01760
01380-01400		03010-03290
03580-03610		03450-03560
03640-03660		

Table 2. Model type (thin-plate regression spline, SP, orthogonal polynomial, OP), numbers relative catch efficiency, dispersion, and total degrees of freedom, dispersion covariates, and log-likelihood for best performing models based on AIC_C.

Rank	Model Type	ρ df	ϕ df	ϕ Covariates	# Total parameters	-LL	AIC_C	Δ (AIC_C)
1	OP(Stock Area)	13	9	SF, SA	22	-1034.27	2113.38	0.00
2	OP-G	5	9		14	-1059.68	2147.70	34.32
3	OP	5	3	SF, SA	8	-1065.98	2148.04	34.66
4	OP-G	3	9		12	-1061.95	2148.16	34.78
5	PS	7.48	3	SF, SA	10.48	-1063.58	2148.30	34.92
6	OP	5	4	SF, SA	9	-1065.11	2148.32	34.94
7	OP-G	4	9		13	-1061.07	2148.44	35.06
8	OP-G	5	1		6	-1068.66	2149.39	36.01
9	OP-G	5	10		15	-1059.64	2149.67	36.29
10	OP-G	6	9		15	-1059.66	2149.71	36.33
11	OP	5	5	SF, SA	10	-1064.93	2149.99	36.61

Table 3. Predicted relative catch efficiencies for the three stock areas from the final calibration model. Values in red are outside of the range of lengths observed for the respective stock area.

Length (cm)	Gulf of Maine	Georges Bank	Southern New England
6	23469.46	13.06	2539.52
7	11462.59	13.05	827.65
8	5757.23	13.05	312.88
9	2973.68	13.04	135.45
10	1579.53	13.03	66.33
11	862.80	12.99	36.31
12	484.67	12.93	21.98
13	279.98	12.84	14.55
14	166.33	12.72	10.43
15	101.61	12.55	8.01
16	63.84	12.34	6.55
17	41.25	12.08	5.64
18	27.40	11.78	5.07
19	18.72	11.44	4.74
20	13.16	11.06	4.57
21	9.51	10.64	4.50
22	7.06	10.20	4.53
23	5.40	9.73	4.61
24	4.24	9.24	4.73
25	3.43	8.75	4.88
26	2.85	8.24	5.04
27	2.44	7.74	5.19
28	2.14	7.25	5.32
29	1.93	6.77	5.42
30	1.80	6.31	5.48
31	1.72	5.87	5.49
32	1.69	5.46	5.45
33	1.71	5.07	5.37
34	1.78	4.71	5.24
35	1.90	4.39	5.09
36	2.09	4.09	4.92
37	2.36	3.83	4.74
38	2.74	3.59	4.57
39	3.28	3.39	4.43
40	4.03	3.22	4.34
41	5.10	3.07	4.30
42	6.63	2.96	4.34
43	8.87	2.88	4.49
44	12.20	2.83	4.79
45	17.25	2.82	5.30

46	25.08	2.85	6.14
47	37.51	2.92	7.49
48	57.70	3.04	9.72
49	91.26	3.23	13.52
50	148.43	3.50	20.39
51	248.28	3.87	33.63
52	427.09	4.38	61.35
53	755.51	5.09	125.15
54	1374.39	6.08	288.90
55	2571.17	7.47	764.01
56	4946.56	9.47	2344.61
57	9786.48	12.42	8462.27
58	19911.34	16.86	36425.66
59	41660.58	23.78	189727.37
60	89639.85	34.91	1213921.55
61	198347.97	53.44	9690867.12

Table 4. Mean swept area (sq. nm) per tow for each vessel at all stations or just those where winter flounder were observed, across all areas or those occurring in the stock areas. Note that swept area is not known for every tow.

		Gulf of Maine	Georges Bank	Southern New England	Overall
Winter flounder observed	Albatross IV	0.0116713	0.0116754	0.0112200	0.0114548
	Henry B. Bigeglow	0.0070750	0.0064268	0.0065834	0.0065460
All stations	Albatross IV	0.0116610	0.0117447	0.0112734	0.0114787
	Henry B. Bigeglow	0.0072050	0.0065790	0.0066452	0.0066689

Figure 1. Randomized quantile residuals of the best performing model (as measured by AICc, see Table 1) for winter flounder in relation to the predicted number captured by the *Henry B. Bigelow* (left), the total number of fish captured at a station (middle), and their normal quantiles (right).

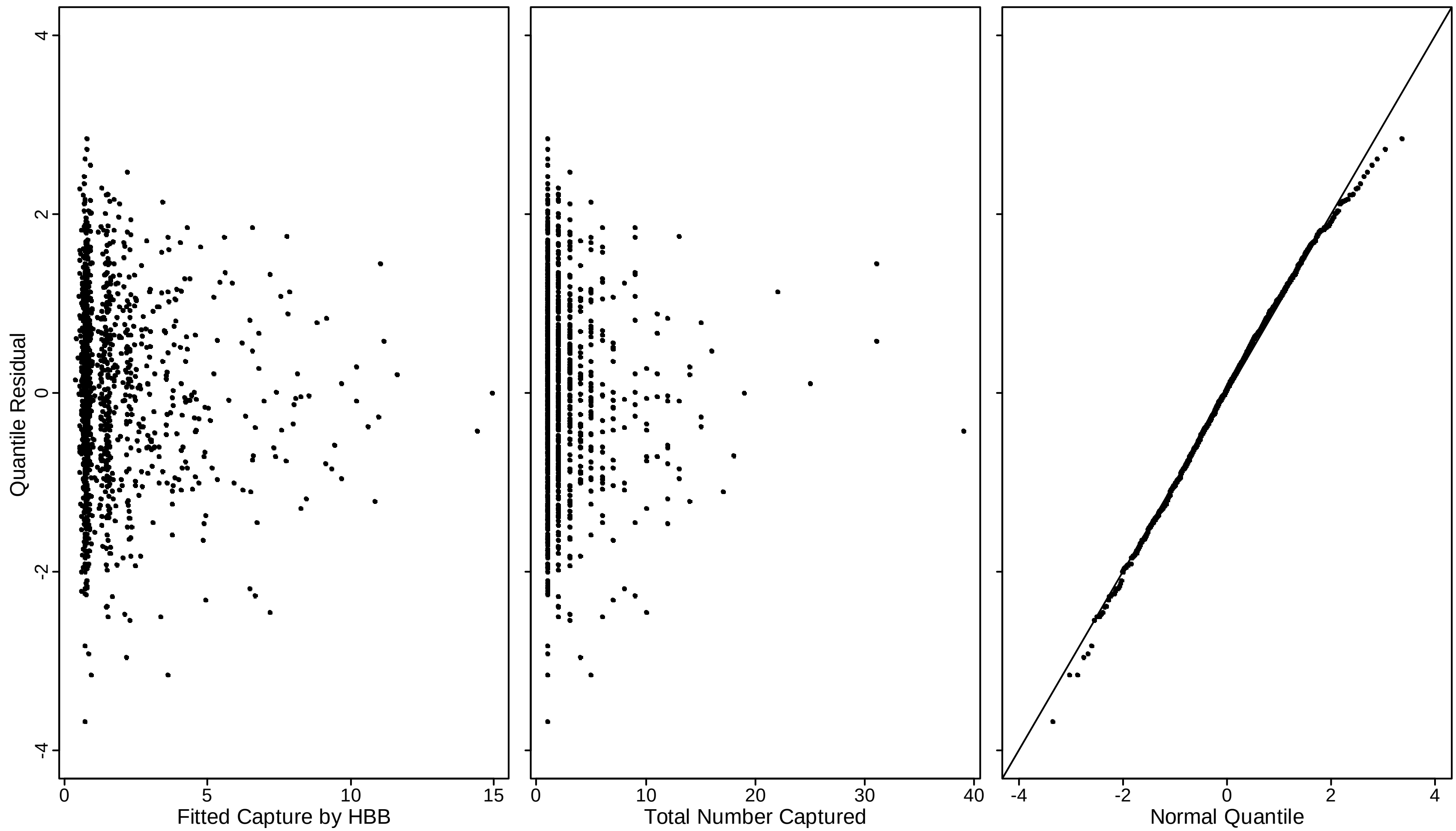
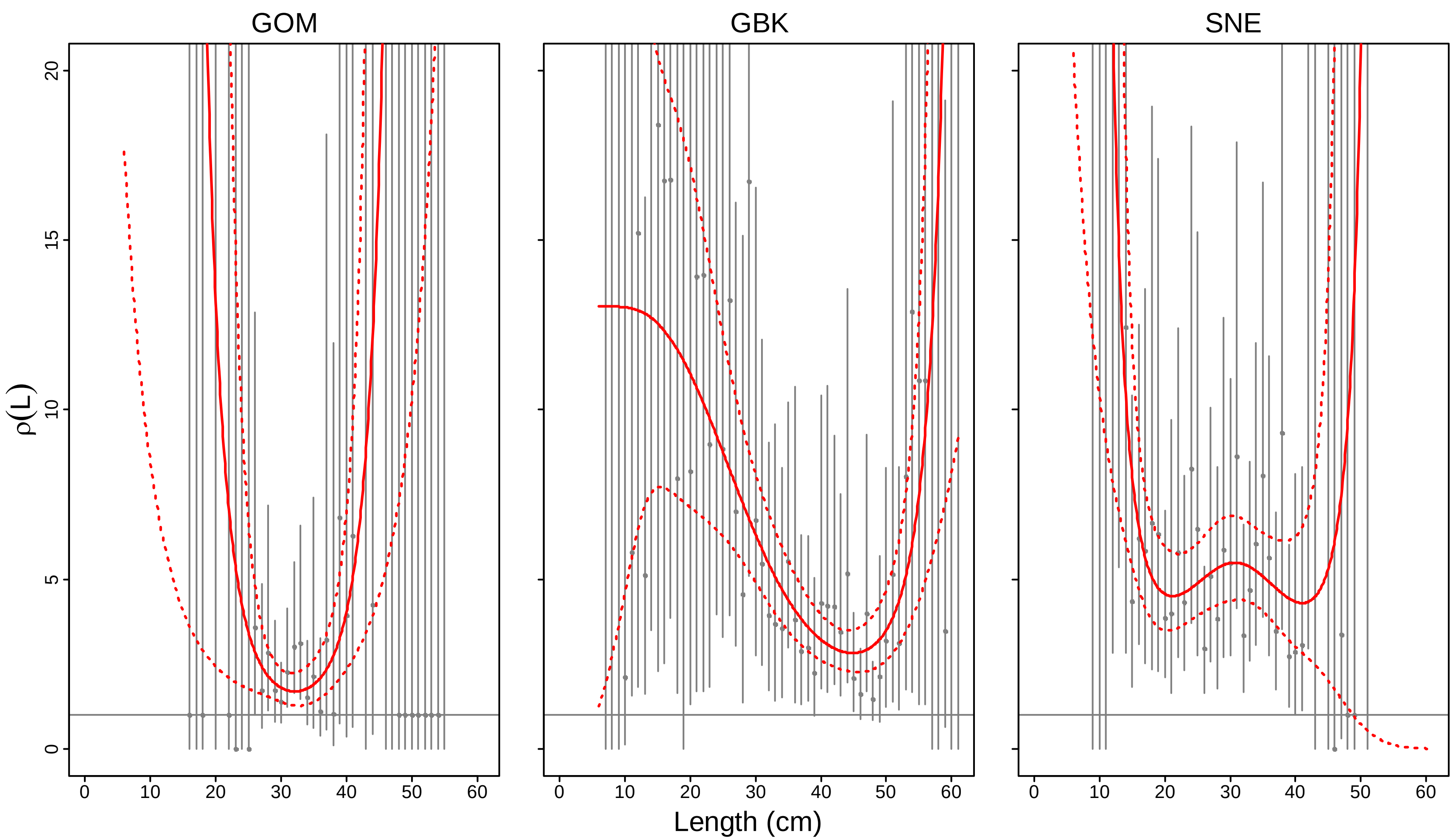


Figure 2. Estimated relative catch efficiency by stock area (columns) from the best beta-binomial model where relative catch efficiency is modeled as an orthogonal polynomial smoother of length (solid red line) and from separate models fit to data in each length class (gray points). Dotted red lines and vertical gray lines represent approximate 95% confidence intervals. Horizontal gray line represents equal efficiency of the *Henry B. Bigelow* and *Albatross IV*.



SDWG Background WP#7 (b)
May 2011
Wint. Fl Length based Calib

Winter Flounder Calibration: WP7

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Beta-Binomial Model

- Binomial model at each station for number captured by Bigelow conditional on number captured by Both (Bigelow + Albatross)

$$N_{Bi}(L) \sim Bin\left(N_i(L), p_i(L)\right)$$

- Probability parameter is random across stations according to beta distribution

$$p_i(L) \sim Beta\left(\pi(L), \phi(L)\right)$$

Mean Model from CRD 10-05

$$\log\left(\frac{\pi}{1-\pi}\right)=\log(\rho)$$

- π is the (mean) probability of capture by the Bigelow
- $\rho = E(C_B)/E(C_A)$ is the calibration factor

Length Models

$$\log\left(\frac{\pi(L)}{1-\pi(L)}\right)=\log\left[\rho\left(L\right)\right]+\log\left(SA_B / SA_A\right)+\log\left(SF_B / SF_A\right)$$

- $\pi(L)$ is the (mean) probability of capture by the Bigelow
- $\rho\left(L\right)$ is the relative catch efficiency (B/A)
- SA is the swept area
- SF is the sampling fraction
- Based on $E(C)=q\times SA\times D$

Dispersion Models

- For orthogonal polynomial and penalized smoothers,

$$\log\left[\phi(L)\right] = \alpha_1 \log\left(SA_B / SA_A\right) + \alpha_2 \log\left(SF_B / SF_A\right) + \varphi(L)$$

- For the gamma-based beta-binomial model,

$$\log\left[\phi(L)\right] = \log\left[SF_A SA_A + \rho(L) SF_B SA_B\right] + \varphi(L)$$

Smoothers for Length Models

$$\log\left[\rho(L)\right] = \sum_{i=0}^{D} \beta_i g_i(L) \qquad \varphi(L) = \sum_{i=0}^{D} \beta_i g_i(L)$$

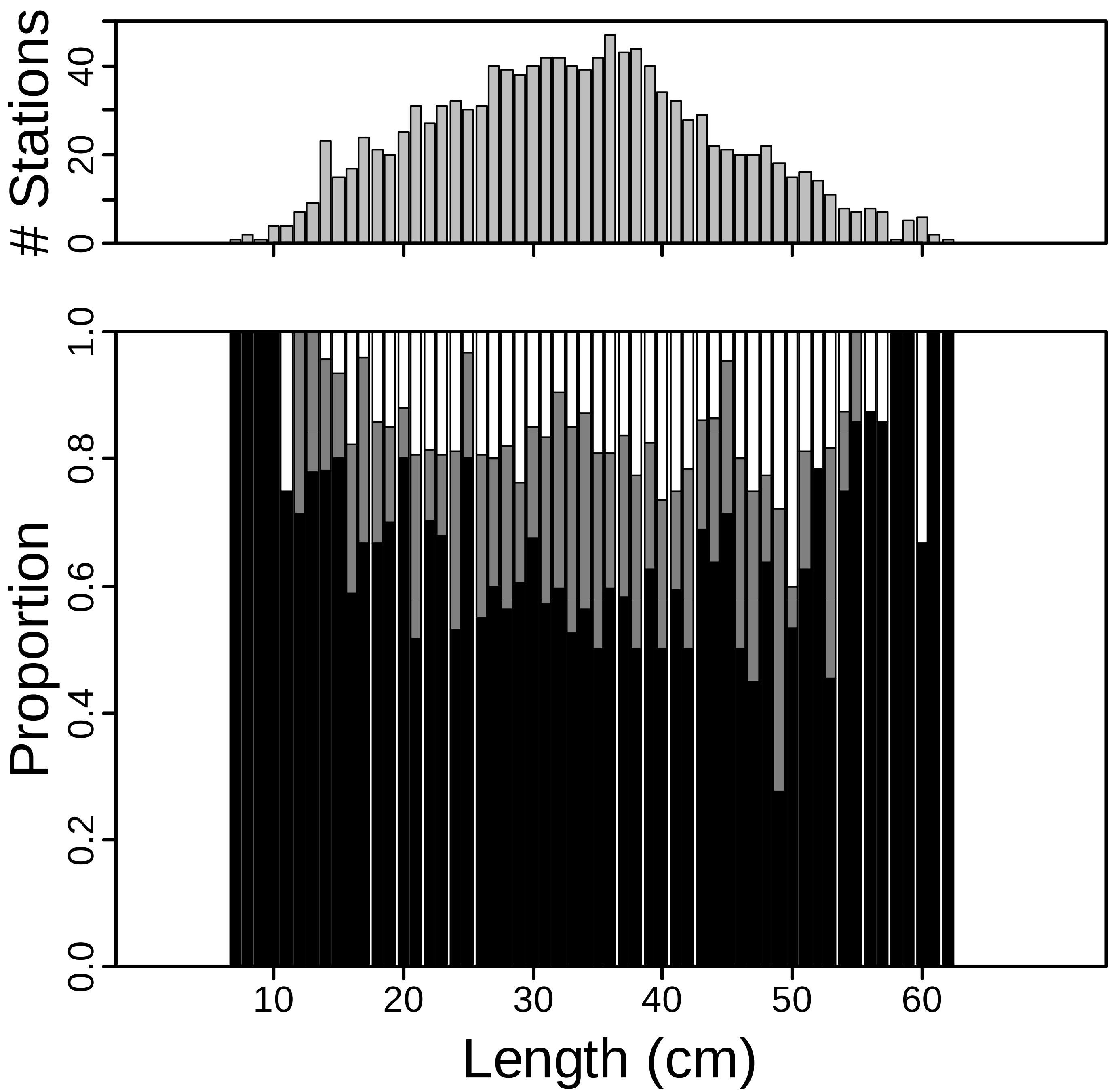
- The more terms, the less smooth the fit can be.
- For orthogonal polynomial, D is the degree of the polynomial and $g_i(L)$ are uncorrelated
  - D ranges from 0 to 12 for both relative catch efficiency and dispersion parameter
- For penalized smoothers $g_i(L)$ are basis components and D is the number of columns of the basis
  - The number parameters is estimated via a penalty term.

By Stock Region

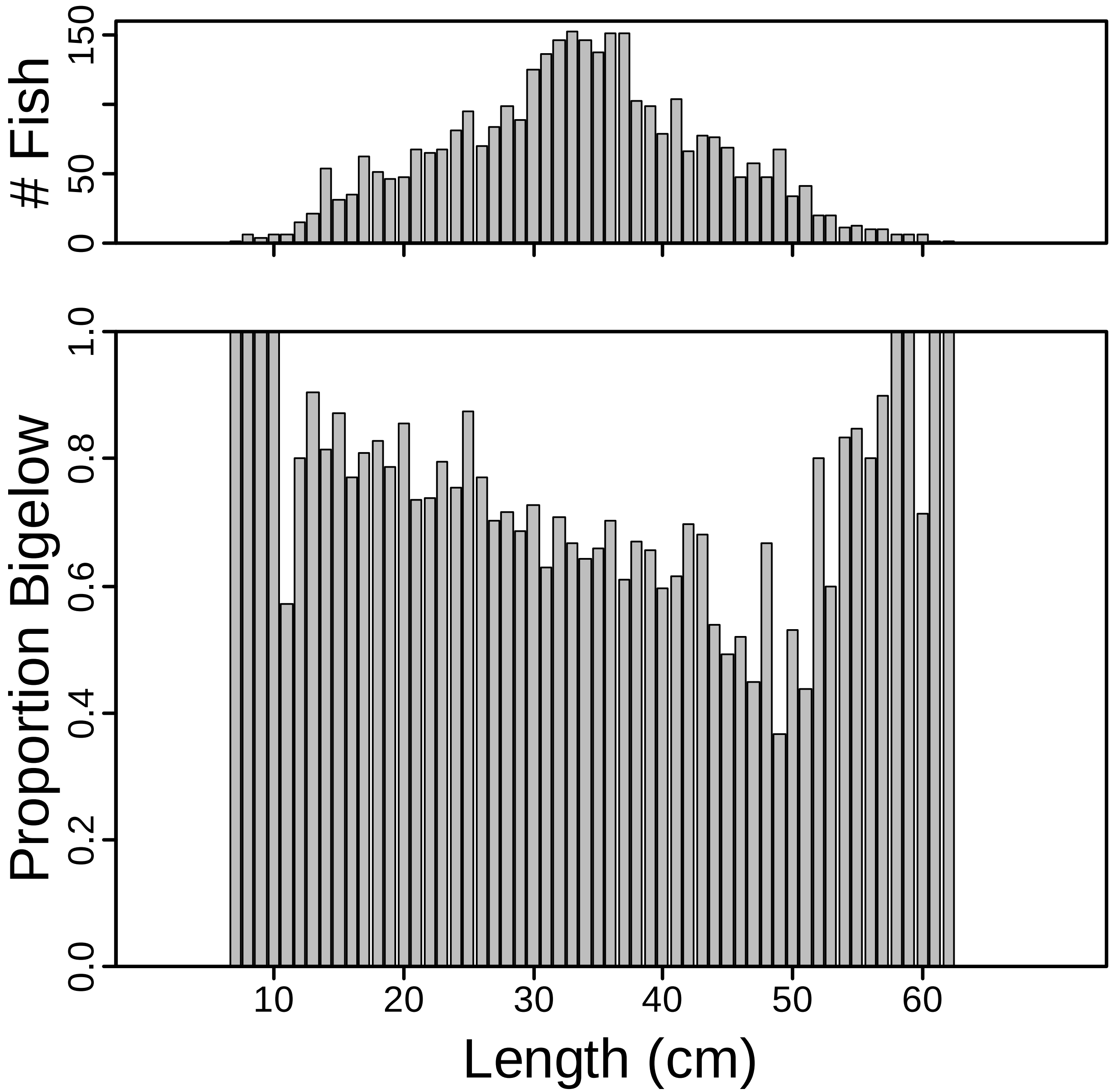
- The catchability of the survey may vary by stock region
  - natural to consider differences in relative catch efficiency too
- Regional strata in Table 1 (slightly different than survey indices)
- All estimated parameters were season-specific
- Seasonal effects were of interest, but no winter flounder data for GOM in spring.

Determining a final model

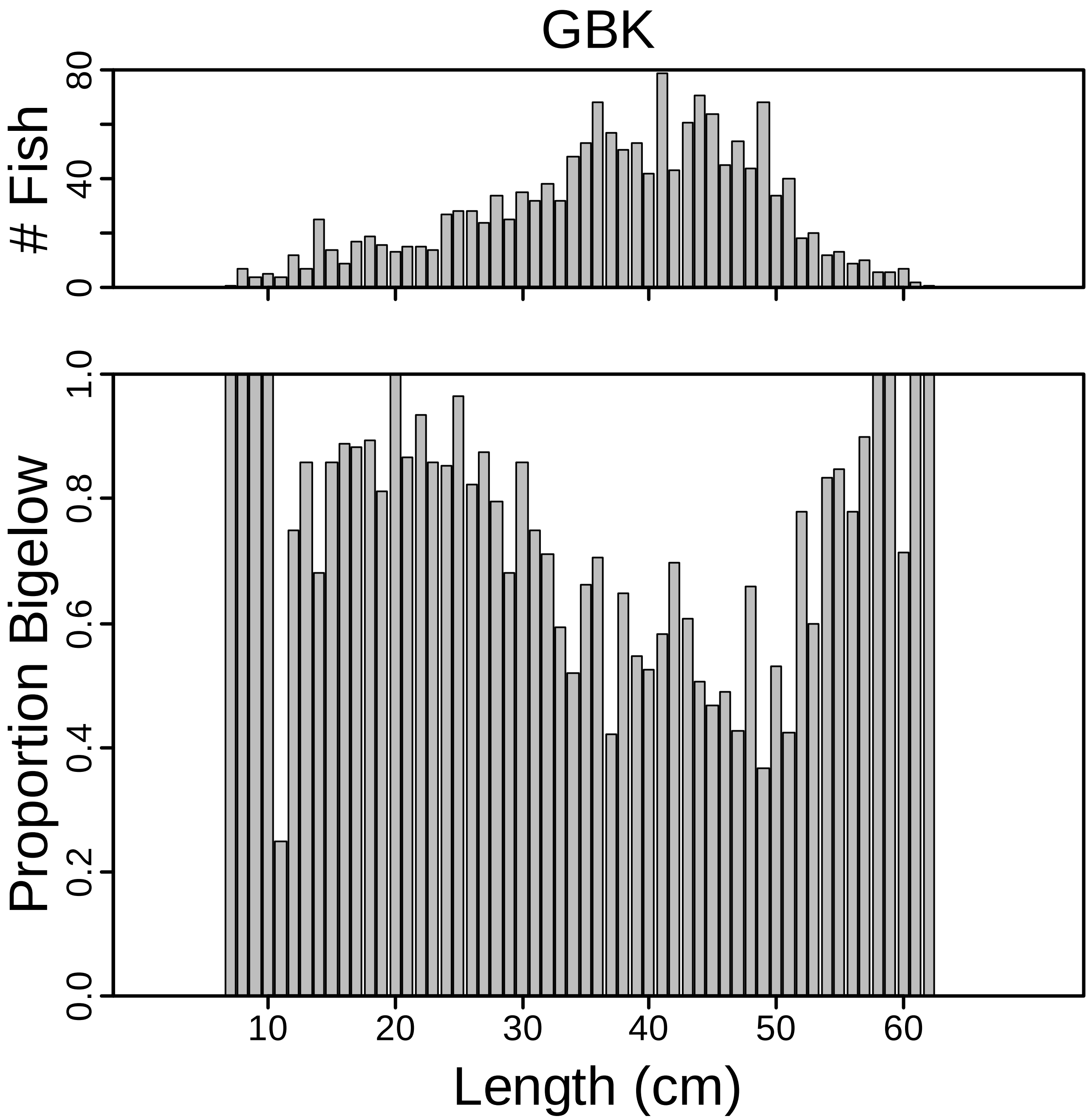
- Before considering stock area
  - The suite of fitted models with different smoothers types and numbers of parameters were compared using AIC_c.
- Then once a type of smoother was chosen,
  - the same type of smoother was used for each stock area.
- The stock area model was also compared to previously fitted models

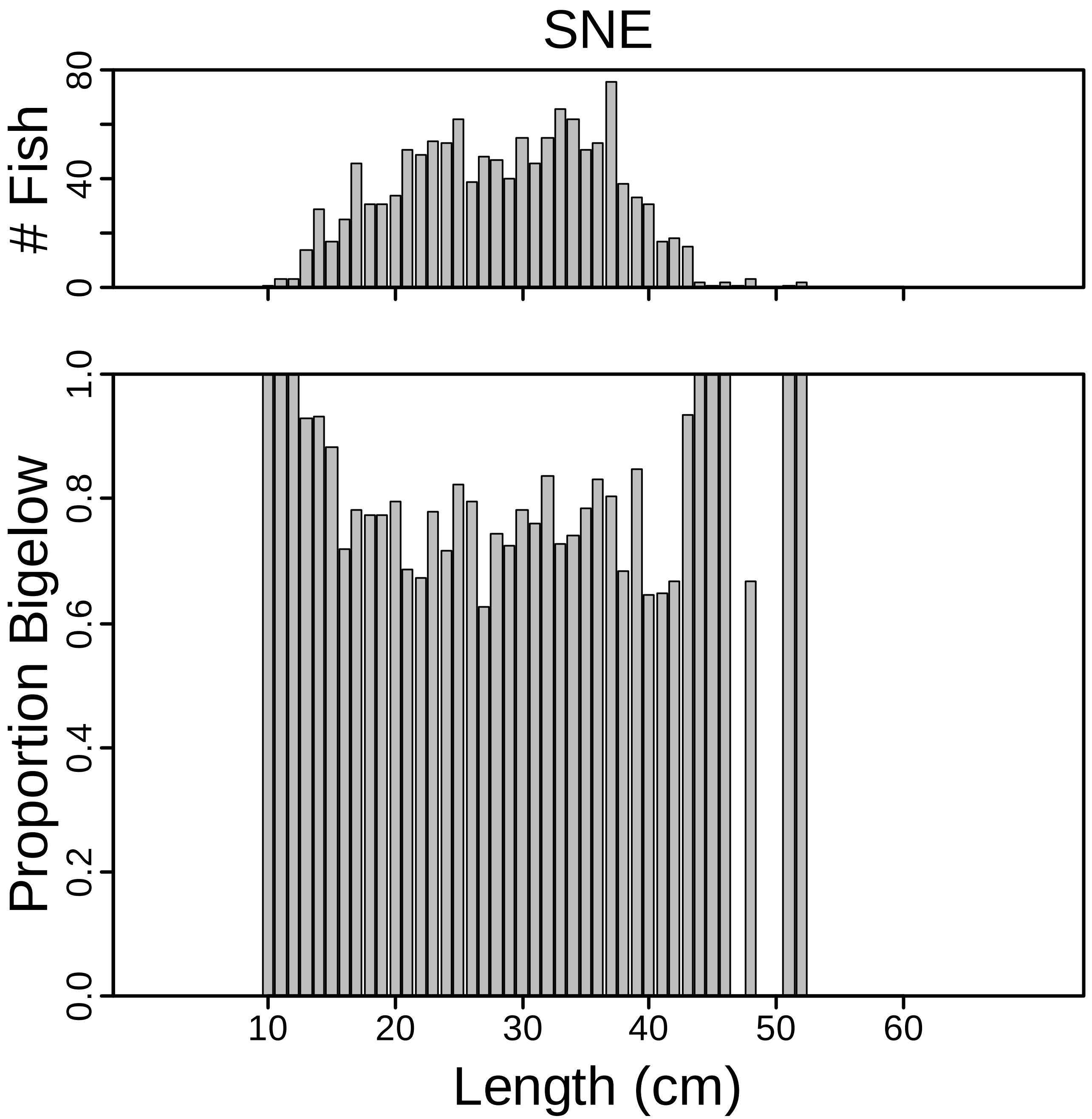


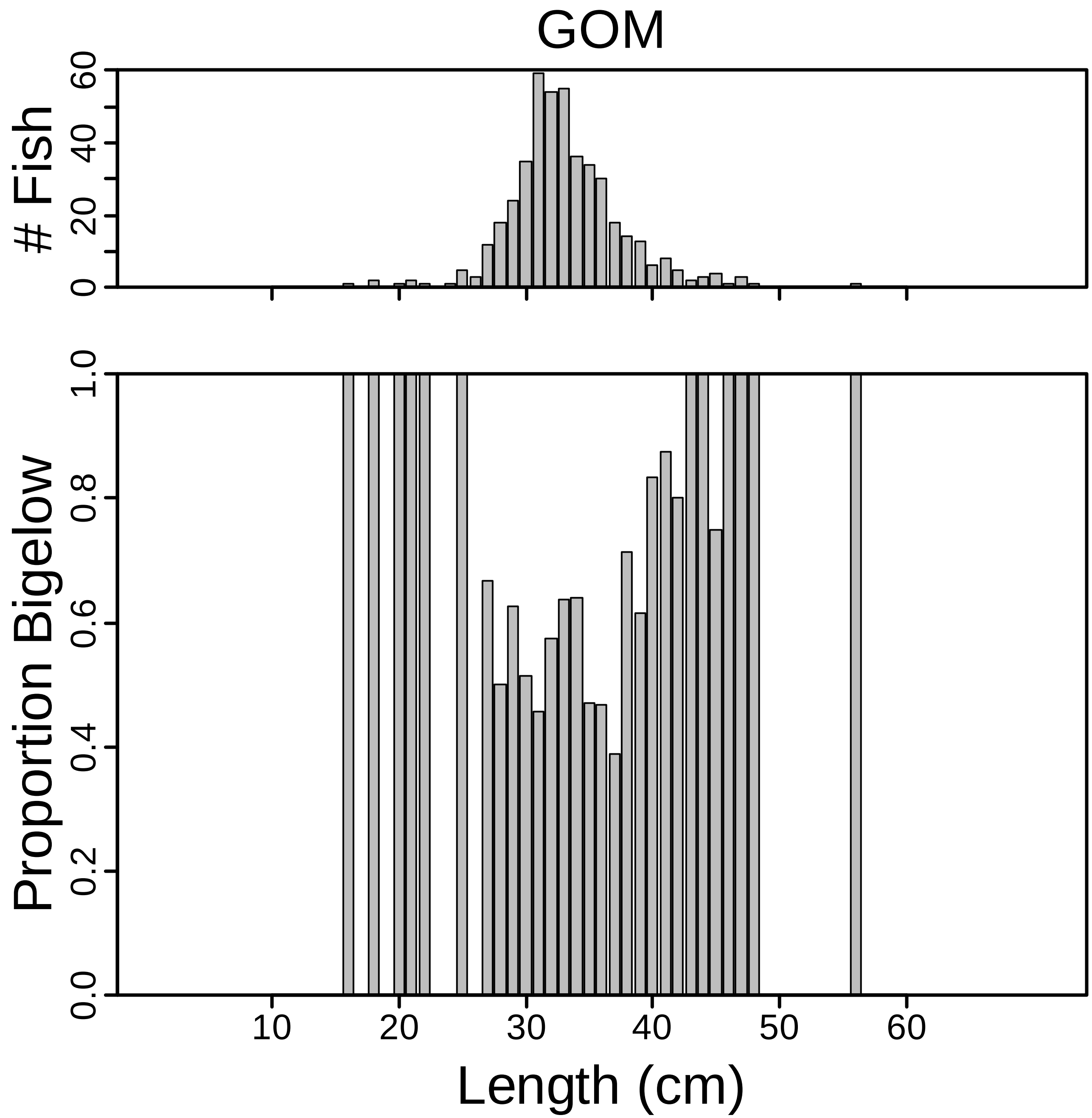
Stations
0
20
40
Proportion
0.0
0.2
0.4
0.6
0.8
1.0
10
20
30
40
50
60
Length (cm)



Fish
150
50
0
Proportion Bigelow
1.0
0.8
0.6
0.4
0.2
0.0
10
20
30
40
50
60
Length (cm)


GBK
Fish
0
40
80
Proportion Bigelow
0.0
0.2
0.4
0.6
0.8
1.0
10
20
30
40
50
60
Length (cm)


SNE
Fish
80
40
0
Proportion Bigelow
1.0
0.8
0.6
0.4
0.2
0.0
10
20
30
40
50
60
Length (cm)



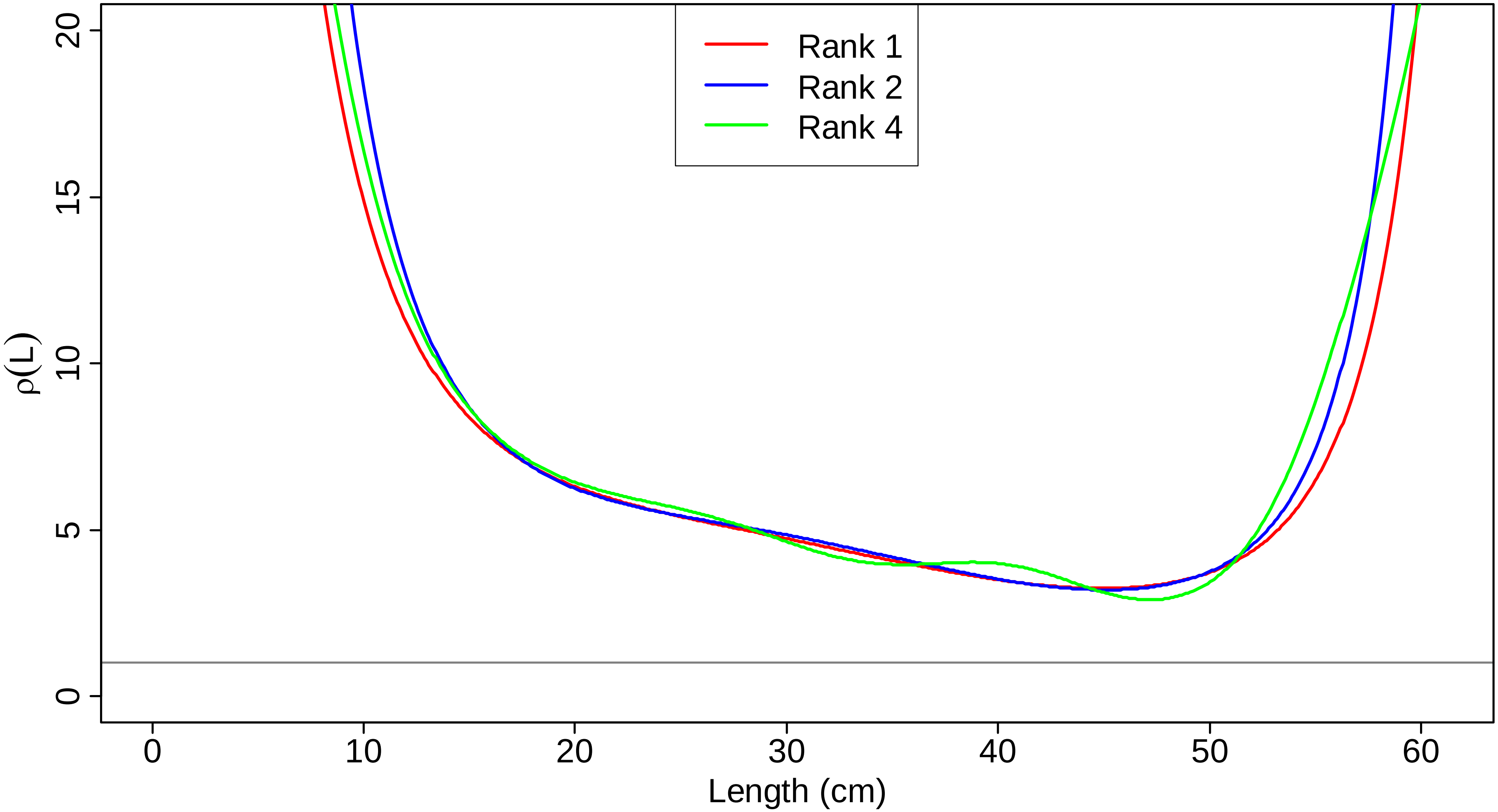
GOM
Fish
0
20
40
60
Proportion Bigelow
0.0
0.2
0.4
0.6
0.8
1.0
10
20
30
40
50
60
Length (cm)

Δ

First round of fitted models

Rank	Model Type	# ρ pars	# ϕ pars	ϕ Covariates	LL	# parameters	AIC_c	$\Delta(AIC_c)$
1	OP-G	5	9		-1059.68	14	2147.698	0
2	OP	5	3	SF,SA	-1065.98	8	2148.041	0.3425
3	OP-G	3	9		-1061.95	12	2148.16	0.462009
4	PS	7.472573	3	SF,SA	-1063.58	10.47257	2148.3	0.601108
5	OP	5	4	SF,SA	-1065.11	9	2148.324	0.62589
6	OP-G	4	9		-1061.07	13	2148.444	0.745977
7	OP-G	5	1		-1068.66	6	2149.389	1.6903
8	OP-G	5	10		-1059.64	15	2149.674	1.97597
9	OP-G	6	9		-1059.66	15	2149.706	2.007345
10	OP	5	5	SF,SA	-1064.93	10	2149.991	2.292643

Top ranked models of each class



Orthogonal Polynomials by Stock Area

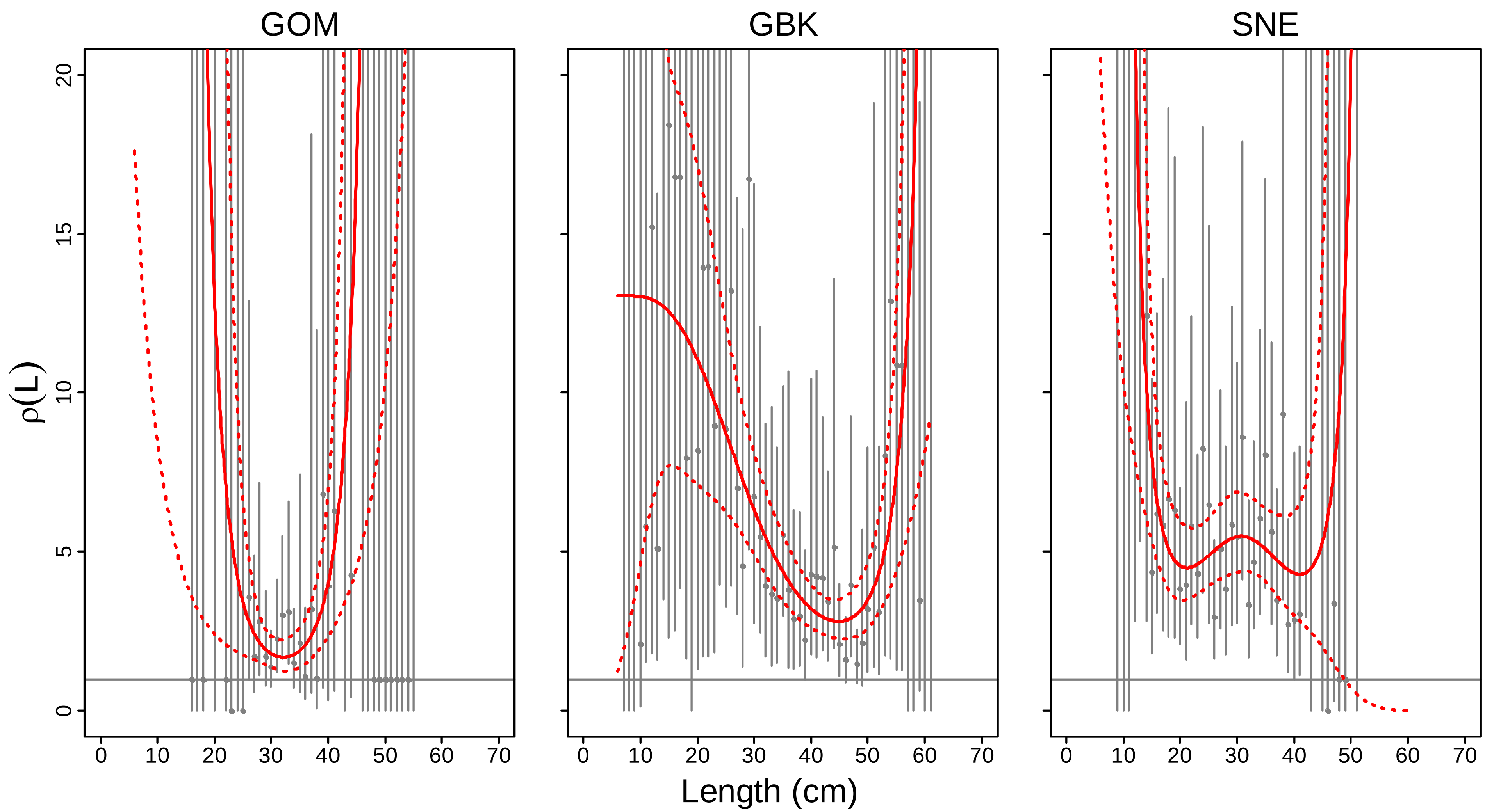
- 4 degree OP in GOM is not well behaved.
  - Over-parameterized for this region. Converges to location with inappropriate variance estimates.
  - 2 degree OP for GOM fits fine
  - Also checked constant relative catch efficiency for GOM

Δ

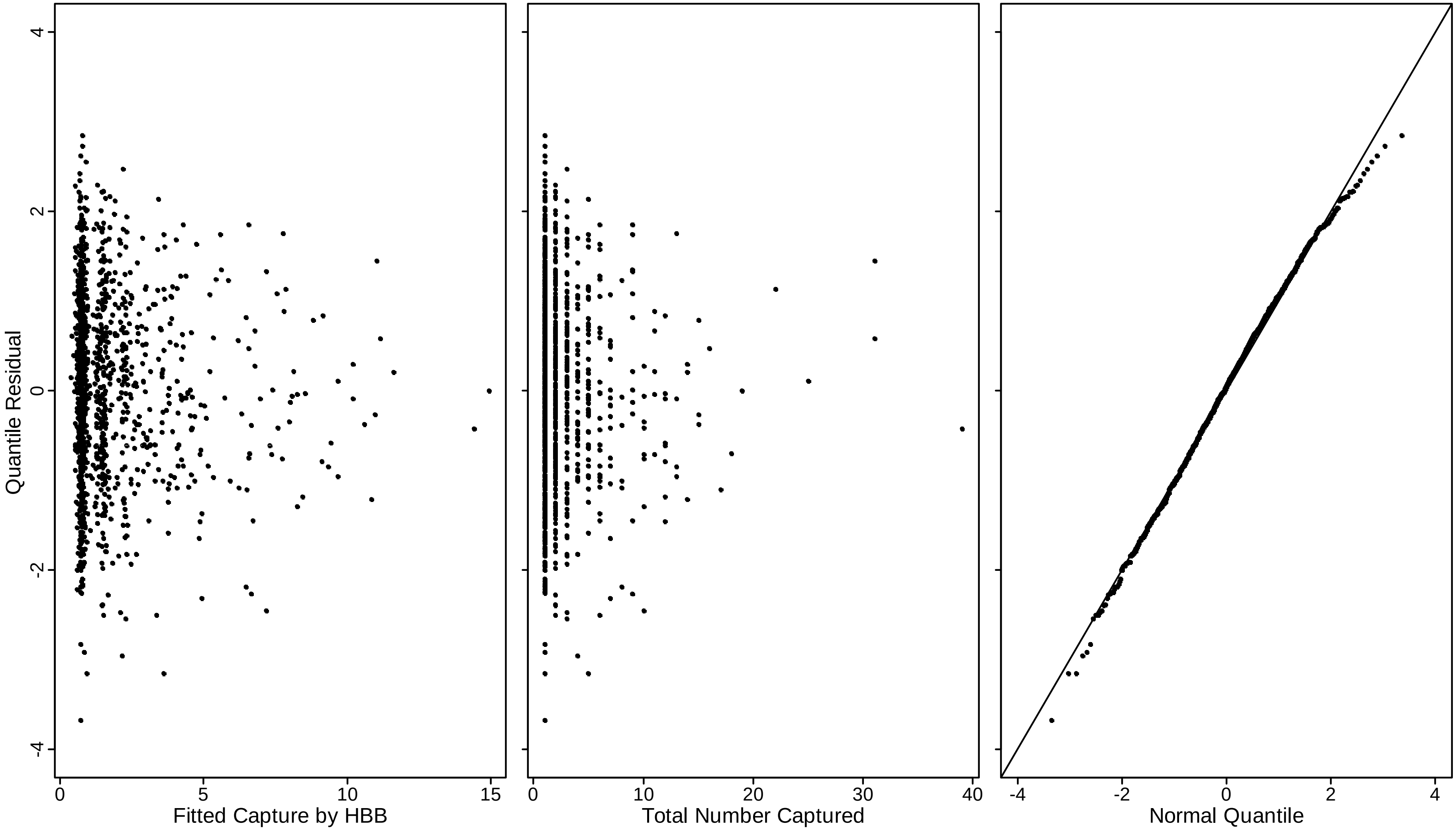
Best Fitted Models

Rank	Model Type	ρ df	ϕ df	ϕ Covariates	# Total parameters	-LL	AIC_c	(AIC_c)
1	OP(Stock Area)	13	9	SF, SA	22	-1034.27	2113.38	0.00
2	OP(Stock Area, GOM constant)	11	9	SF, SA	20	-1041.90	2124.49	11.11
3	OP-G	5	9		14	-1059.68	2147.70	34.32
4	OP	5	3	SF, SA	8	-1065.98	2148.04	34.66
5	OP-G	3	9		12	-1061.95	2148.16	34.78
6	PS	7.48	3	SF, SA	10.48	-1063.58	2148.30	34.92
7	OP	5	4	SF, SA	9	-1065.11	2148.32	34.94
8	OP-G	4	9		13	-1061.07	2148.44	35.06
9	OP-G	5	1		6	-1068.66	2149.39	36.01
10	OP-G	5	10		15	-1059.64	2149.67	36.29
11	OP-G	6	9		15	-1059.66	2149.71	36.33
12	OP	5	5	SF, SA	10	-1064.93	2149.99	36.61

WP7 Figure 2



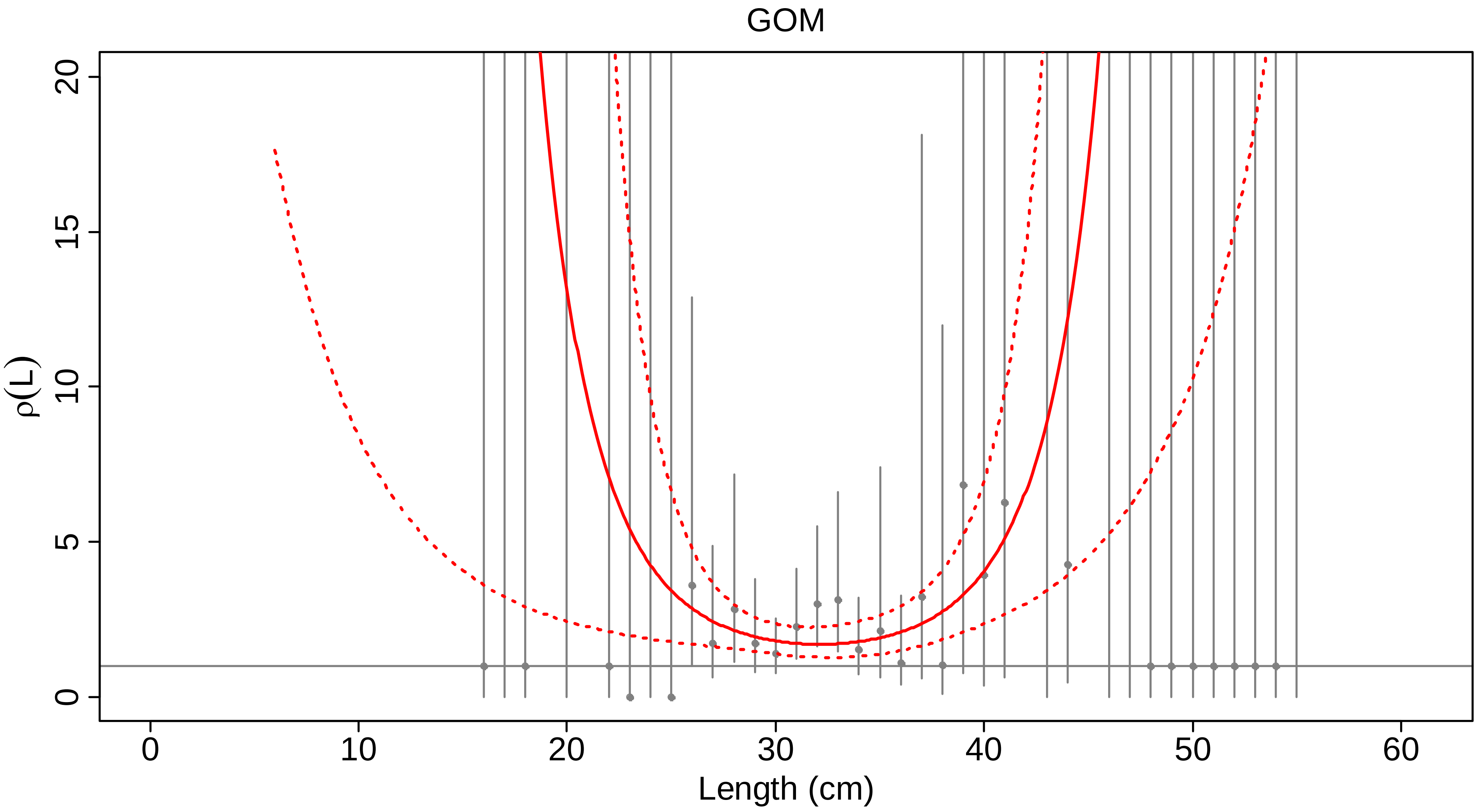
Residuals of best fitted model



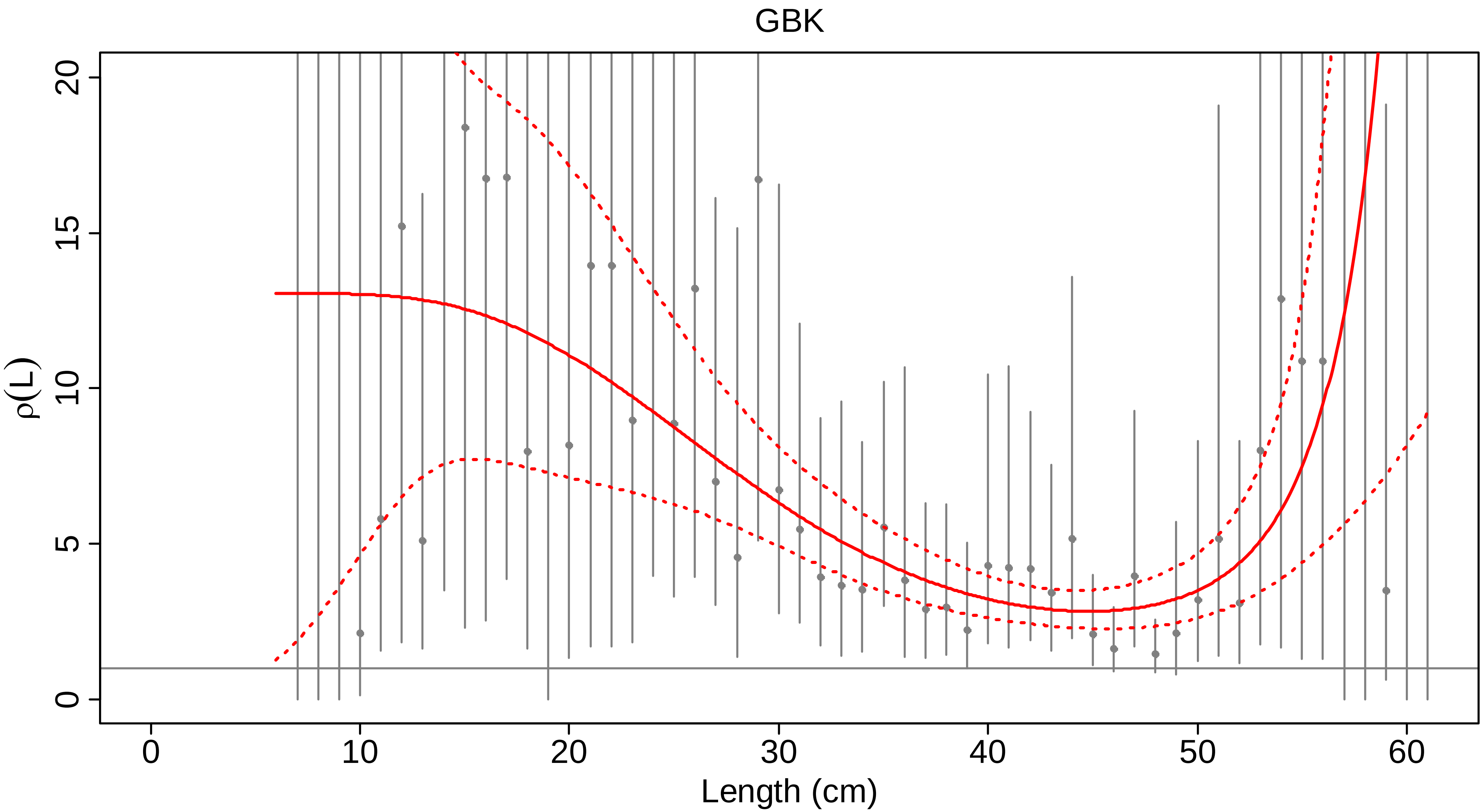
Application

- The ranges of lengths observed during the calibration study defines the limits of prediction for 2009 on (Table 3)
- The mean swept areas (Table 4) are used with the relative catch efficiencies

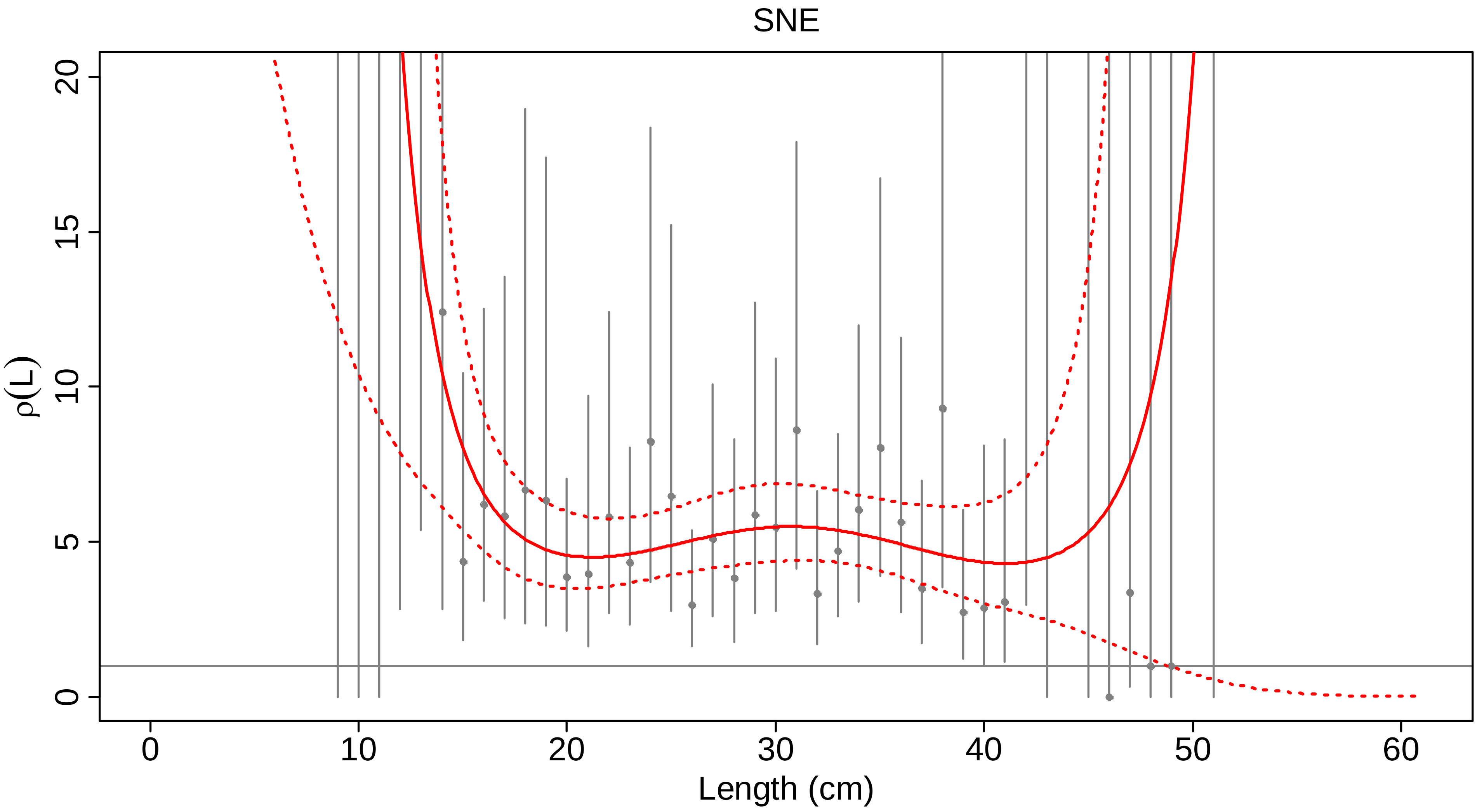
Predicted Relative Catch Efficiency (Fig 2a)



Predicted Relative Catch Efficiency (Fig 2b)



Predicted Relative Catch Efficiency (Fig 2c)



Classifying female winter flounder maturity during NEFSC resource surveys: comparing at-sea, macroscopic maturity classifications with results from a gonad histology method

A working paper for SARC 52

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April 15, 2011

1.0 Background

Fish maturity needs to be assigned accurately to estimate spawning stock biomass (SSB). A common benchmark for stock assessment is to maintain a fishing rate at or lower than the rate necessary to achieve a SSB that is 20 to 40% of the estimated virgin spawning biomass (Berger, 2009). When such benchmarks are being used, accurate maturity data are necessary.

Maturity classification schemes artificially break up a continuous process into discrete classes, so all other things equal, there is a tradeoff between precision (more classes) and accuracy (fewer classes). The number of maturity classes can vary by species, sex, method, and purpose of each monitoring program or research project; as evident at dozens of fishery laboratories, the number ranges from four to ten (ICES, 2007).

For cost reasons, maturity is typically classified by a macroscopic method, examining characters such as gonad size, color, texture, or shape using fresh, dissected fish. At the Northeast Fisheries Science Center (NEFSC), there is a long history developing maturity schema, and currently, a six-class macroscopic maturity scheme is used for routine monitoring at sea (Burnett et al., 1989; Appendix Table 1). During NEFSC resource surveys, female winter flounder maturity is classified using a six-class, I-D-R-U-S-T scheme.

The I-D-R-U-S-T scheme has one immature class (I). Briefly, immature fish have a small ovary and a thin gonad wall; the immature gonad is either clear or translucent and may have color later in its development. There are five mature classes. Mature females are identified by the presence of yolked oocytes (developing eggs) preceding or during the spawning season or by evidence that a fish has spawned in the past. Briefly, females that are developing (D) have yolked oocytes (yellowish, opaque); females that are ripe (R) have hydrated (dark, clear) oocytes; females that are running ripe (U) naturally express hydrated oocytes from their vent (i.e., without pressing the abdomen); females that are spent (S) have a flaccid and often hollow, opaque gonad, which if cut open, residual eggs can often be observed; and females that are resting (T) have a small, firm ovary with a thick, opaque gonad wall.

Conceptually, a fish is only immature (I) once, and once it is mature, it cycles between developing (D), spawning (R-U), and mature but inactive (S, T) classes each year (Figure 1a). Recent evidence that fish can mature but then not spawn in every subsequent year (i.e., skip spawning; Rideout et al., 2005) has not been incorporated into the NEFSC six-class scheme as of yet.

In NEFSC stock assessments of winter flounder, maturity is determined from spring survey data using the logistic model. All years in the time series have been pooled because there was little evidence for a change in maturation over time. Three U.S. winter flounder stocks are recognized: southern New England (includes more southern strata offshore of middle Atlantic states [SNE/MA]), Georges Bank, and Gulf of Maine. All three stocks are sampled by the NEFSC spring and fall resource survey; data are also available from the State of Massachusetts' (MDMF) inshore surveys of southern New England and Gulf of Maine stocks.

At SARC 36 (2002), differences in maturity parameters of the inshore stocks were noted when using data from one survey dataset or the other. The MDMF survey consistently estimated a median age at maturity (A_{50}) to be one year older than estimates from the NEFSC survey, as calculated for both the Gulf of Maine and Southern New England stocks. Survey overlap or timing did not seem to explain the difference in the maturity schedule. The more conservative parameters (i.e., older, larger size at maturity) have been used for the inshore stocks. For example, using the MDMF spring data for 1978-2007, the SNE/MA median size at maturity, L_{50}, is 28.4 cm, and the A_{50} is 2.9 years (M. Terceiro, pers. comm.). No alternative data source exists for Georges Bank, and there has been no independent verification of which, if any, parameters are correct.

The purpose of this study was to validate the accuracy of at-sea, macroscopic maturity classifications. Gonad histology was used to independently reexamine the tissue collected from the same fish that were examined at sea. Two-way tables were used to compare agreement of maturity assignments between the two methods. Since the gonad histology method can recognize more cytological details – which can be measured quantitatively and reexamined more than once and by more than one reader – the gonad histology method was expected to produce the correct maturity class with few exceptions (which will be noted below). Sources of error for misidentifications, options for remedy, and the ramifications with regard to defining spawning stock biomass are all discussed.

2.0 Methods

2.1 At-sea collections and ageing

Winter flounder females were collected during routine marine resource surveys conducted by the NEFSC. Collections occurred during 2007-2010 when two research vessels, the *R/V Albatross IV* and the *F/R/V Henry B. Bigelow*, were operating. Biologists were requested to sample one fish from two size groups per station when winter flounder were collected. The size threshold was 25 cm or 28 cm in various years. Very small, immature fish (i.e., < 10 cm) were not collected. A one cubic centimeter piece of fresh tissue was excised from the middle of one of the ovarian lobes and fixed in 10% buffered formalin. Ages were obtained using scales or otoliths following standard NEFSC protocols (Penttila and Dery, 1988).

2.2 Gonad histology

Gonad tissue fixed at sea was later trimmed to an approximately 1 mm thick subsample and preserved in 70% ethyl alcohol. These subsamples were sent in labeled histology cassettes to an outside firm, Mass Histology Service Inc., dehydrated further in increasing ethyl alcohol concentrations, and embedded in wax. Thin sections (5 μm) of tissue were stained using either: 1) Schiffs-Mallory trichrome (SMT) or 2) hematoxylin and eosin (H&E). The use of two different staining methods did not confound interpretation of the samples. A test set (n = 12) of samples were stained using both methods and detailed comparisons have been completed, calibrated, and reported (Rowinski et al. 2010).

2.3 Assignment to maturity class

At sea, macroscopic characters were used to assign maturity. These characters are briefly described in the background section (1.0) and expanded on in Appendix Table 1.

In the lab, histology slides were examined using a Nikon Coolscope II. The majority of material has been examined by two readers, some material has been examined more than twice. The most advanced oocyte stage (MAOS) was recorded as: chromatin nucleolar (CN), perinucleolar (PG), late cortical alveolar (LC), early vitellogenic (V1), late vitellogenic (V2), germinal vesicle migration (GM), nucleus breakdown one (inside the follicle, B1), and nucleus breakdown two (outside the follicle, B2). The absence (0) or presence (some = 1, lots = 2) of postovulatory follicles (POFs) and their relative age (1-3) was recorded. The thickness of the gonad wall (tunica, 1 = thin [< 100 microns], 2 = thick) and gonad stroma were evaluated. Atresia and presence of encysted eggs were also recorded.

Two algorithms were developed in SAS (SAS, 1999) to assign maturity based on gonad histology characters (Appendix Table 2). If the MAOS was CN, then the fish was immature. If the MAOS was PG or LC, then the fish was either immature or it was mature but inactive with regard to spawning. If MAOS was V1, then the gonad was developing, the first sign that a recruit spawner was maturing for the first time or a repeat spawner was redeveloping. Later vitellogenesis (V2) characterized a developing fish, GM and B1 cells indicated oocyte maturation, the B2 was characteristic of active spawning. The presence of POFs and the thickness of the gonad wall and stroma were also diagnostic characters used in the SAS algorithms to indicate recent or past spawning. Some subroutines were season specific to permit assignment of maturing clases as mature or not in a spawning season or calendar year.

A gonad histology scheme was recently developed for winter flounder (Wuenschel et al. 2010), and additional samples collected since and additional discussions have refined this scheme (Fig. 1b). SAS programming code from Wuenschel et al. (2010) was reiteratively modified to match histology-based classifications appropriately with at-sea classifications and to check for outliers or data errors. SAS algorithms assigned histology-based maturity to both the standard I-D-R-U-S-T scheme as well as to an expanded ten-class scheme (Appendix Table 2). The former was used to compare between at-sea and laboratory assignments, whereas the latter was used to investigate oocyte development and maturation processes in greater detail.

2.4 Modeling maturity schedules

All fish not assigned as immature (I, Im, If, Fig. 1) were mature according to both maturity schema. Maturity ogives were fitted to the logistic model using binary coding (0 = immature, 1 = mature) and SAS programming (i.e., PROC LOGISTIC). McBride et al. (2010) compared the logit, probit, and complementary log-log models using the Akaike information criterion. They concluded that the logit model was the most appropriate for parameter estimates of median size at maturity, so this model is used here without further comparison.

3.0 Results and Discussion

3.1 Sample size

A total of 371 winter flounder females were collected on spring and fall cruises from 2007 to 2010 for this analysis (Table 1). Fish were collected aboard the *R/V Albatross IV* in 2007 and 2008 (*n* = 156; Table 2) as well as aboard the *F/R/V Henry B. Bigelow* in 2008, 2009, and 2010 (*n* = 215; Table 2). Fish were collected in all three stock areas managed by U.S. fishery management councils (southern New England [*n* = 177; Table 3], Georges Bank [*n* = 91; Table 3], Gulf of Maine [*n* = 65]; Table 3), as well as on the Scotian Shelf (*n* = 38; Table 3) in Canadian waters. Fish were collected in both survey seasons: spring (*n* = 288; Table 4) and fall (*n* = 83; Table 4).

A total of 362 winter flounder females were aged from southern New England (1, 3, 8 [minimum, median, maximum age], *n* = 176), Georges Bank (1, 3, 14, *n* = 84), Gulf of Maine [1, 4, 8, *n* = 64), and the Scotian Shelf (2, 5, 7, *n* = 38).

3.2 Agreement between methods

A total of 96 of 158 immature fish were correctly identified as immature, and 211 of 213 mature fish were correctly identified as mature. Immature fish smaller than 19 cm were classified correctly, and mature fish larger than 39 cm were classified correctly (Fig. 2). The developing class was consistently classified correctly; > 80% of the time and often >95% of the time by sampling ship, flounder stock, or season (Tables 2-4).

3.3 Minor mismatches between methods

A high rate of exact matches was not expected nor required when the transition between two adjacent maturity classes was subjective. The best example of this was the transition between spent (S) and resting (T) classes. When spent and resting classes were combined the agreement between at-sea and laboratory assignments was consistently > 90%. Such mismatches between separate spent and resting (S,T) classes have little effect to stock assessment results because both classes are mature.

Another source of minor mismatch is when at-sea classification may be more accurate than gonad histology. Although this is unusual, it is not unexpected during certain active classes of spawning, such as when hydrated oocytes first appear but are lightly scattered throughout the gonad (ripe, R) or when they first ovulate and begin to fill the lumen (running ripe, U). The maturity assignment for such fish was best made by examining whole fish and their whole gonad instead of the very small sliver of gonad tissue that was analyzed histologically. Thus, when ripe and running-ripe classes were combined, agreements between the two methods increased to 100% in most cases. Again, such mismatches do not affect the stock assessment because both classes are mature.

3.4 A major mismatch between methods

One particular mismatch was not inconsequential. Specifically, 61 fish identified as immature using gonad histology (i.e., labClass = I), were assigned as resting at sea (i.e., seaClass = T). This occurred on both sampling ships (Table 2), in all stock areas (Table 3), and in both seasons (Table 4). Misclassifying immature females as resting was most common among the largest immature fish (Tables 5, 6; Fig. 2). No females smaller than 19 cm total length were misclassified, but all immature fish larger than 33 cm were misclassified as resting.

All first-developing females were misclassified as resting (Fig. 2). First-developing fish collected in spring were larger (27-34 cm total length [TL]) than other immature fish (Table 6); these fish were preparing to spawn in the next year, 10-12 months ahead of their first spawning event. First-developing fish collected in the fall were the largest of all misidentified immature fish (30-39 cm; Table 6); these fish, many of which had partially yolked oocytes (V1), were preparing to spawn in the next year, 5-6 months ahead. First-developing females are distinguishable from other immature females, based on color of the gonad in particular, but they all had a thin gonad wall as measured from histological preparations of the gonad, and they showed no evidence of past spawning, so first-developing females are immature by definition.

3.5 Preliminary female maturity schedules, by stock

Median length at female maturity (L_{50}) occurred within a narrow length range, 29-30 cm TL, for the inshore stocks (Table 7a). Females from the Georges Bank stock matured at a much larger size, L_{50} = 33.6 cm TL (Table 7a).

These L_{50} values are consistent with another analysis of gonad histology using the fish included here, as well as more material from state surveys (Massachusetts, Rhode Island, Connecticut), totaling nearly 800 females (McBride et al. 2010). Nonetheless, these L_{50} estimates should be considered preliminary. Sampling has continued on NEFSC surveys since spring, 2010, and other valuable material has been collected on state surveys and by cooperating industry research boats (i.e., the study fleet), which can be used in further analysis.

Median age at female maturity (A_{50}) occurred as young as age 2 (2.6-2.7 years for Georges Bank and southern New England) but was 1-2 years older in more northern stocks (3.7 for Gulf of Maine and 4.7 for Scotian Shelf) (Table 7b).

This analysis does not account for the frequency of mature but non-spawning fish (i.e., skip spawners). Skipping may be > 20% in northern stocks of winter flounder but is not typically that high in U.S. stocks in a typical year (McBride et al., 2010; McElroy et al., 2011). Skip spawning has been defined as non-participation in a spawning event among mature fish (Rideout et al., 2005), so in using this definition, skipping rates do not affect the estimation of size or age of maturity.

3.6 Causes of error and options for remedy

Keypunch errors may occur but the touch-screen data entry system used at sea should make keypunch error unlikely. In addition, there are limits to histology and there is ambiguity between certain macroscopic classes, which was evident by mismatches between the ripe (R) and running-ripe (U) classes as well as the spent (S) and resting (T) classes. These examples are minor errors that do not bias the interpretation of spawning stock biomass and do not appear to require any comprehensive remedy.

The misclassification of immature and first-time developing fish as mature, resting fish is more problematic. It inflates the estimate of spawning stock biomass among relatively young but abundant age classes.

This type of error was broadly distributed among NEFSC staff, contractors, and volunteers. Although fish were not assigned randomly to the biologists for sampling, a total of 67 individuals (i.e., 'cutters') made maturity determinations of these 371 winter flounder females. No cutter identified the maturity of more than 30 fish, and the majority of cutters identified the maturity of fewer than five fish. Among this diverse pool of biologists, almost half (n = 31) misclassified at least one of the 61 immature fish as resting. The maximum number of this type of misclassifications per cutter was five.

Early on in the study, we were generally interested in having cutters identify 'difficult-to-identify gonads.' Some cutters may have selected fish that were difficult to classify, which would inflate the magnitude of the error. Again, neither the assignment of the cutters nor the selection of the fish was random, so this report cannot identify the precise nature of the error. Instead it simply notes that this is a specific source of error that affects characterization of spawning stock biomass.

The problem warrants continued training by way of regular maturity workshops using fresh fish. These occur regularly after the first three legs of the spring and the fall resource surveys. The summary statistics presented here suggest that all sea-going biologists will benefit from attending these workshops.

Also, better use of photographic images should be made to standardize maturity classification and reduce misclassification of immature fish as resting, mature fish. Photographs of fish at sea demonstrate the ambiguities between classes and can be used to set standards (Fig. 3), but the quality of images taken at sea is often unsatisfactory. Photographs of fish taken in the laboratory may not be as fresh but they generally can be of higher resolution or compositional quality (Fig. 4).

Displays such as Figure 4 are posted in the NEFSC main building cutting room and have been highlighted during the spring, 2011, maturity workshops. Looking ahead, sampling of gonad tissue should stop this spring and resume in a few years to test the effectiveness of such training.

One alternative to at-sea, macroscopic classifications is to fit maturity ogives based on gonad histology only. This is a costly option if used routinely but it could be done periodically to validate at-sea, macroscopic methods as was done here. If it is done infrequently, so that it only creates parameter estimates for a short time interval, variance around these point estimates can be used to model the effect of uncertainty.

Another alternative is to establish a set of decision rules to appropriately reclassify all or most resting fish as immature from prior spring surveys. This may be a reasonable approach considering that more immature fish are misclassified as resting than there are resting fish during spring (Table 4b). Such a reclassification would assume similar error rates and biases throughout the time series.

A third alternative is to create an age-based decision rule for classifying spawning stock biomass. In such an approach, all fish older than a certain age would be classified as mature. In such a case, macroscopic determination of maturity class at sea would cease and the age-maturity relationship could be periodically validated by gonad histology.

4.0 Acknowledgements

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Table 1. Sample sizes (N = number of fish) by year, season, stock and survey vessel. Survey vessels (SVVESSEL) are the Albatross IV (AL) and the Henry Bigelow (HB).Female winter flounder collected by NEFSC monitoring only.

		stock								
		Georges Bank		Gulf of Maine		Southern New England		Scotian Shelf		
		SVVESSEL		SVVESSEL		SVVESSEL		SVVESSEL		
		AL	HB	AL	HB	AL	HB	AL	HB	All
		N	N	N	N	N	N	N	N	N
EST_YEAR	SEASON									
2007	FALL	8	.	5	.	15	.	8	.	36
	SPRING	8	.	7	.	37	.	9	.	61
2008	FALL	.	6	.	.	.	.	.	.	6
	SPRING	8	.	.	.	38	.	13	.	59
2009	FALL	.	20	.	12	.	9	.	.	41
	SPRING	.	26	.	17	.	39	.	2	84
2010	SPRING	.	15	.	24	.	39	.	6	84
All		24	67	12	53	90	87	30	8	371

Table 2. Survey vessel-specific matches of maturity assignments. A 6-class scheme is used to match at sea (seaClass) and in lab (labClass) assignments. Survey Vessels (SVVESSEL) are the Albatross IV (AL) and the Henry Bigelow (HB). Frequency = number of fish, Col Pct = Percentage of each cell in relation to entire column. Female winter flounder collected by NEFSC monitoring only.

-- SVVESSEL=AL --

seaClas2 / labClas2 Frequency Col Pct	1_I	2_D	3_R	4_U	5_S	6_T	Total
1_I	42 56.00	0 0.00	0 0.00	0 0.00	0 0.00	2 5.71	44
2_D	0 0.00	29 90.63	0 0.00	0 0.00	0 0.00	0 0.00	29
3_R	0 0.00	1 3.13	1 100.00	1 100.00	1 8.33	0 0.00	4
4_U	0 0.00	1 3.13	0 0.00	0 0.00	0 0.00	0 0.00	1
5_S	0 0.00	0 0.00	0 0.00	0 0.00	2 16.67	10 28.57	12
6_T	33 44.00	1 3.13	0 0.00	0 0.00	9 75.00	23 65.71	66
Total	75	32	1	1	12	35	156

-- SVVESSEL=HB --

seaClas2 / labClas2 Frequency Col Pct	1_I	2_D	3_R	4_U	5_S	6_T	Total
1_I	54 65.06	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	54
2_D	0 0.00	76 93.83	0 0.00	0 0.00	1 4.55	1 3.85	78
3_R	1 1.20	0 0.00	0 0.00	1 50.00	0 0.00	0 0.00	2
4_U	0 0.00	0 0.00	1 100.00	1 50.00	0 0.00	0 0.00	2
5_S	0 0.00	2 2.47	0 0.00	0 0.00	20 90.91	10 38.46	32
6_T	28 33.73	3 3.70	0 0.00	0 0.00	1 4.55	15 57.69	47
Total	83	81	1	2	22	26	215

Table 3. Stock-specific matches of maturity assignments. A 6-class scheme is used to match at sea (seaClass) and in lab (labClass) assignments. Frequency = number of fish, Col Pct = Percentage of each cell in relation to entire column.Female winter flounder collected by NEFSC monitoring only.

------------------------------------- stock=Georges Bank -------------------------------------

seaClas2 labClas2

Frequency Col Pct	1_I	2_D	3_R	4_U	5_S	6_T	Total
1_I	27 75.00	0 0.00	0 0.00	0 0.00	0 0.00	1 8.33	28
2_D	0 0.00	26 81.25	0 0.00	0 0.00	0 0.00	0 0.00	26
3_R	0 0.00	0 0.00	1 50.00	0 0.00	0 0.00	0 0.00	1
4_U	0 0.00	0 0.00	1 50.00	1 100.00	0 0.00	0 0.00	2
5_S	0 0.00	2 6.25	0 0.00	0 0.00	7 87.50	3 25.00	12
6_T	9 25.00	4 12.50	0 0.00	0 0.00	1 12.50	8 66.67	22
Total	36	32	2	1	8	12	91

------------------------------------- stock=Gulf of Maine -------------------------------------

seaClas2 labClas2

Frequency Col Pct	1_I	2_D	5_S	6_T	Total
1_I	17 54.84	0 0.00	0 0.00	0 0.00	17
2_D	0 0.00	27 96.43	0 0.00	0 0.00	27
3_R	1 3.23	1 3.57	0 0.00	0 0.00	2
5_S	0 0.00	0 0.00	4 100.00	1 50.00	5
6_T	13 41.94	0 0.00	0 0.00	1 50.00	14
Total	31	28	4	2	65

Table 3 (cont.). Stock-specific matches of maturity assignments. A 6-class scheme is used to match at sea (seaClass) and in lab (labClass) assignments. Frequency = number of fish, Col Pct = Percentage of each cell in relation to entire column.Female winter flounder collected by NEFSC monitoring only.

---------------------------------- stock=Southern New England ----------------------------------

seaClas2 labClas2

Frequency / Col Pct	1_I	2_D	4_U	5_S	6_T	Total
1_I	42 58.33	0 0.00	0 0.00	0 0.00	1 2.38	43
2_D	0 0.00	38 97.44	0 0.00	1 4.55	1 2.38	40
3_R	0 0.00	0 0.00	2 100.00	1 4.55	0 0.00	3
4_U	0 0.00	1 2.56	0 0.00	0 0.00	0 0.00	1
5_S	0 0.00	0 0.00	0 0.00	11 50.00	15 35.71	26
6_T	30 41.67	0 0.00	0 0.00	9 40.91	25 59.52	64
Total	72	39	2	22	42	177

------------------------------------- stock=Scotian Shelf -------------------------------------

The FREQ Procedure

Table of seaClas2 by labClas2

seaClas2 labClas2

Frequency / Col Pct	1_I	2_D	6_T	Total
1_I	10 52.63	0 0.00	0 0.00	10
2_D	0 0.00	14 100.00	0 0.00	14
5_S	0 0.00	0 0.00	1 20.00	1
6_T	9 47.37	0 0.00	4 80.00	13
Total	19	14	5	38

Table 4. Season-specific matches of maturity assignments. A 6-class scheme is used to match at sea (seaClass) and in lab (labClass) assignments. Seasons are Spring (March-May) and Fall (September-November). Frequency = number of fish, Col Pct = Percentage of each cell in relation to entire column. Female winter flounder collected by NEFSC monitoring only.

-- SEASON=FALL --

seaClas2 labClas2

Frequency Col Pct	1_I	2_D	6_T	Total
1_I	19 47.50	0 0.00	0 0.00	19
2_D	0 0.00	25 80.65	1 8.33	26
5_S	0 0.00	2 6.45	0 0.00	2
6_T	21 52.50	4 12.90	11 91.67	36
Total	40	31	12	83

-- SEASON=SPRING --

seaClas2 labClas2

Frequency Col Pct	1_I	2_D	3_R	4_U	5_S	6_T	Total
1_I	77 65.25	0 0.00	0 0.00	0 0.00	0 0.00	2 4.08	79
2_D	0 0.00	80 97.56	0 0.00	0 0.00	1 2.94	0 0.00	81
3_R	1 0.85	1 1.22	1 50.00	2 66.67	1 2.94	0 0.00	6
4_U	0 0.00	1 1.22	1 50.00	1 33.33	0 0.00	0 0.00	3
5_S	0 0.00	0 0.00	0 0.00	0 0.00	22 64.71	20 40.82	42
6_T	40 33.90	0 0.00	0 0.00	0 0.00	10 29.41	27 55.10	77
Total	118	82	2	3	34	49	288

Table 5a. Sample size and proportions of all female winter flounder collected. A 10-class maturity scheme using gonad histology is used; (the 6-class equivalent). The first two classes are immature (never spawned), the other classes are mature (have spawned). Skippers have spawned in the past but are not spawning this year. Female winter flounder collected by NEFSC monitoring only.

TenClass	Frequency	Percent	Cumulative Frequency	Cumulative Percent
(I) Immature - never spawned	147	39.62	147	39.62
(I) Imm., 1st-time developing	11	2.96	158	42.59
(D) Developing - Mature	96	25.88	254	68.46
(D) Oocyte Maturation-Initial	17	4.58	271	73.05
(R) Oocyte Maturation-Hydrated	2	0.54	273	73.58
(U) Oocyte Maturation-Ovulated	3	0.81	276	74.39
(S) Spent - Just spawned	34	9.16	310	83.56
(T) Resting - Has spawned	45	12.13	355	95.69
(T) Re-developing - Mature	15	4.04	370	99.73
(T) Skipper - Has spawned	1	0.27	371	100.00

Table 5b. Simple statistics of fish size for all female winter flounder collected. A 10-class maturity scheme using gonad histology is used; (the 6-class equivalent). The first two classes are immature (never spawned), the other classes are mature (have spawned). Skippers have spawned in the past but are not spawning this year. Female winter flounder collected by NEFSC monitoring only.

Analysis Variable : TL_mm

TenClass	N Obs	N	Mean	Std Dev	Minimum	Maximum
(I) Immature - never spawned	147	147	243.0	52.2	120.0	346.0
(I) Imm., 1st-time developing	11	11	327.7	34.0	268.0	390.0
(D) Developing - Mature	96	96	382.8	70.7	250.0	570.0
(D) Oocyte Maturation-Initial	17	17	364.1	66.4	270.0	540.0
(R) Oocyte Maturation-Hydrated	2	2	480.0	169.7	360.0	600.0
(U) Oocyte Maturation-Ovulated	3	3	495.3	41.1	450.0	530.0
(S) Spent - Just spawned	34	34	373.1	61.3	280.0	560.0
(T) Resting - Has spawned	45	45	345.9	42.6	194.0	440.0
(T) Re-developing - Mature	15	15	385.1	77.6	270.0	556.0
(T) Skipper - Has spawned	1	1	370.0	.	370.0	370.0

Table 6a. Sample size and proportions of immature fish misidentifed as mature, resting. According to the 10-class maturity scheme, these fish are immature and have never spawned. Female winter flounder collected by NEFSC monitoring only.

-- SEASON=FALL --

The FREQ Procedure

TenClass	Frequency	Percent	Cumulative Frequency	Cumulative Percent
(I) Immature - never spawned	16	76.19	16	76.19
(I) Imm., 1st-time developing	5	23.81	21	100.00

-- SEASON=SPRING --

The FREQ Procedure

TenClass	Frequency	Percent	Cumulative Frequency	Cumulative Percent
(I) Immature - never spawned	34	85.00	34	85.00
(I) Imm., 1st-time developing	6	15.00	40	100.00

Table 6b. Simple statistics of fish size of immature fish misidentifed as mature, resting. According to the 10-class maturity scheme, these fish are immature and have never spawned. Female winter flounder collected by NEFSC monitoring only.

-- SEASON=FALL --

Analysis Variable : TL_mm

TenClass	N Obs	N	Mean	Std Dev	Minimum	Maximum
(I) Immature - never spawned	16	16	283.6	37.2	210.0	346.0
(I) Imm., 1st-time developing	5	5	343.4	39.4	297.0	390.0

-- SEASON=SPRING --

Analysis Variable : TL_mm

TenClass	N Obs	N	Mean	Std Dev	Minimum	Maximum
(I) Immature - never spawned	34	34	282.3	35.1	191.0	340.0
(I) Imm., 1st-time developing	6	6	314.7	25.0	268.0	340.0

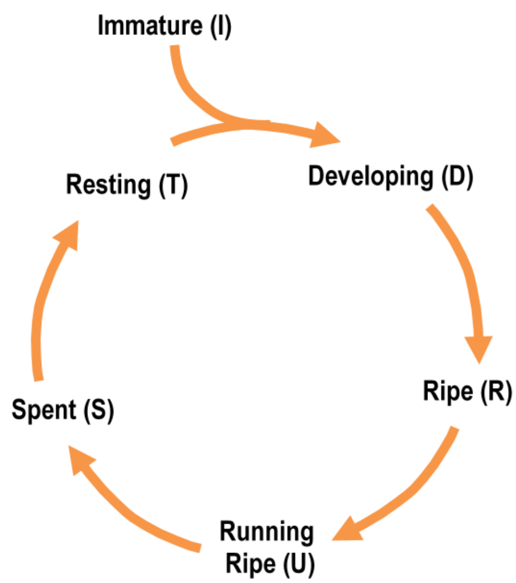
Table 7a. Stock-specific logistic regression of maturity in relation to fish size. Size is measured as total length to the nearest mm (median size at maturity [L50]). Maturity (0=immature, 1=mature) determined by gonad histology. Female winter flounder collected by NEFSC monitoring only.

stock	_LINK_	_STATUS_	Intercept	TL_mm	_LNLIKE_	L50
Georges Bank	LOGIT	0 Converged	22.7450	-0.067756	-11.7151	335.690
Gulf of Maine	LOGIT	0 Converged	13.2772	-0.045413	-21.2714	292.365
Southern New England	LOGIT	0 Converged	13.8801	-0.046448	-53.6985	298.833
Scotian Shelf	LOGIT	0 Converged	14.5187	-0.048414	-16.0243	299.886

Table 7b. Stock-specific logistic regression of maturity in relation to fish age. Age is measured in years (median age at maturity [A50]). Maturity (0=immature, 1=mature) determined by gonad histology. Female winter flounder collected by NEFSC monitoring only.

stock	_LINK_	_STATUS_	Intercept	AGE	_LNLIKE_	A50
Georges Bank	LOGIT	0 Converged	5.10427	-1.98083	-29.6927	2.57683
Gulf of Maine	LOGIT	0 Converged	8.13547	-2.18084	-21.1679	3.73043
Southern New England	LOGIT	0 Converged	5.81909	-2.17224	-62.9812	2.67884
Scotian Shelf	LOGIT	0 Converged	3.52308	-0.75186	-22.3841	4.68581

A)



B)

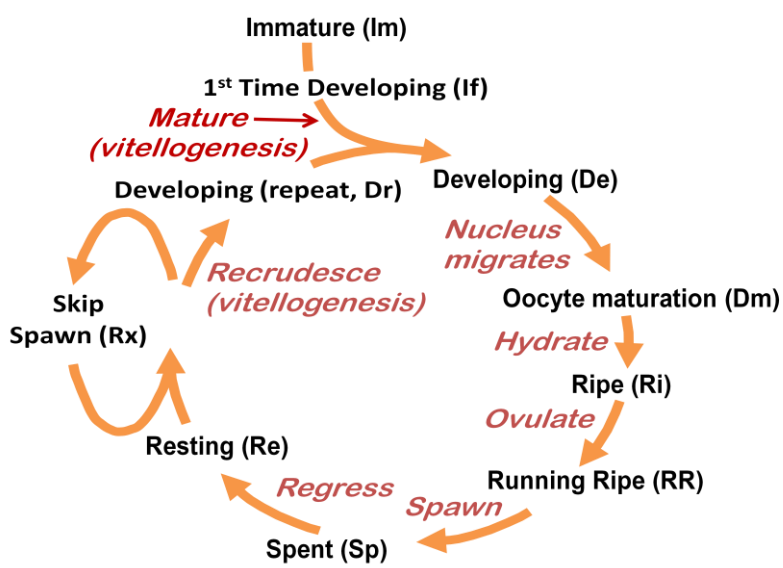


Figure 1. Two complementary maturity schemes for winter flounder (*Pseudopleuronectes americanus*) females. (A) The standard six-class NEFSC maturity scheme used at sea by examining fresh gonads macroscopically, and (B) and an expanded ten-class maturity scheme suitable if gonad histology is available. See also Wuenschel et al. (2010) for comparisons of these two schemes.

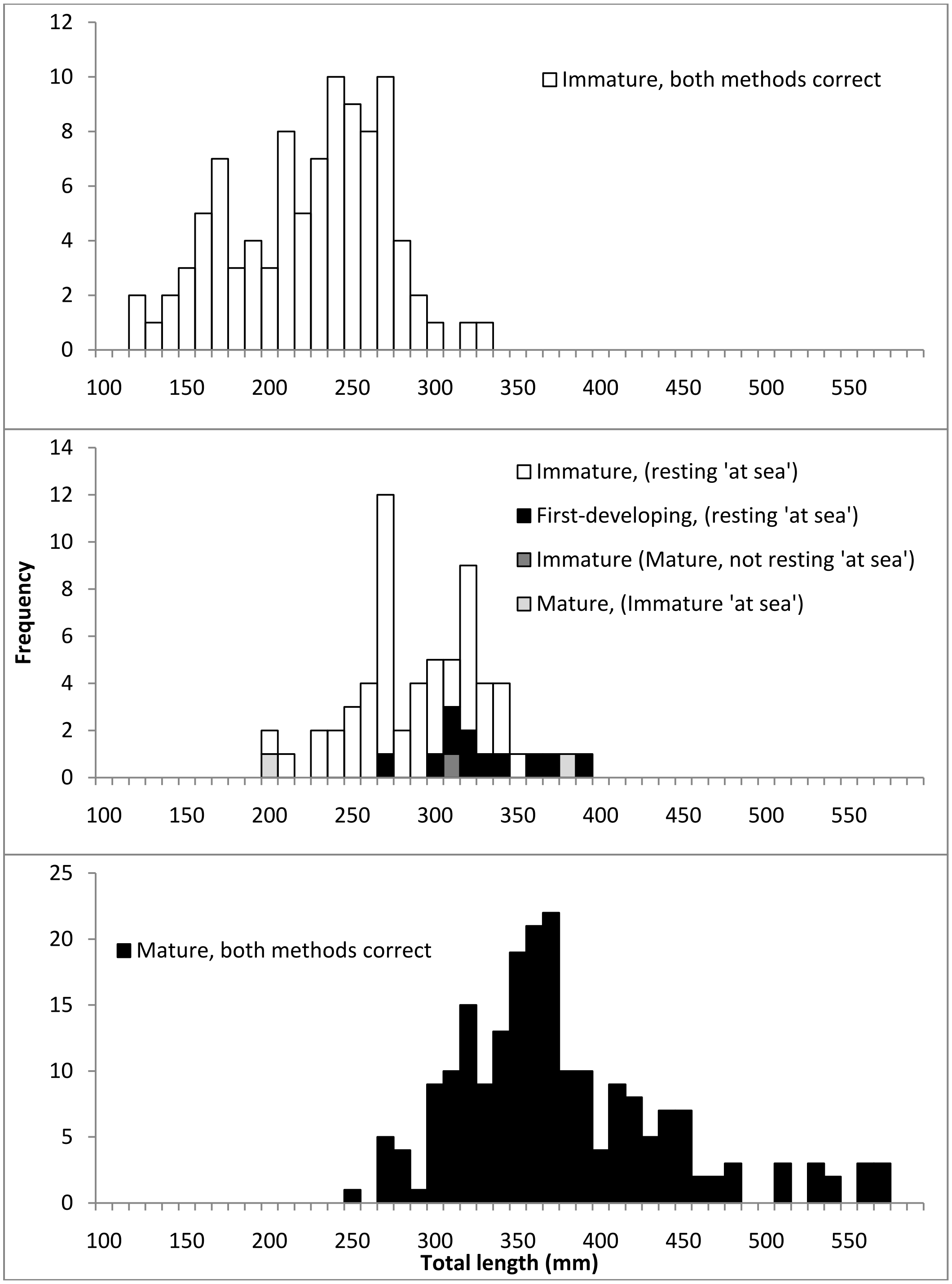


Figure 2. Size distributions of winter flounder (*Pseudopleuronectes americanus*) females. Status of at-sea classifications fall into three groups: immature, correctly identified both at sea and by histology (top panel); incorrect identifications (middle panel, see legend); mature, correctly identified at sea and by histology (bottom panel).

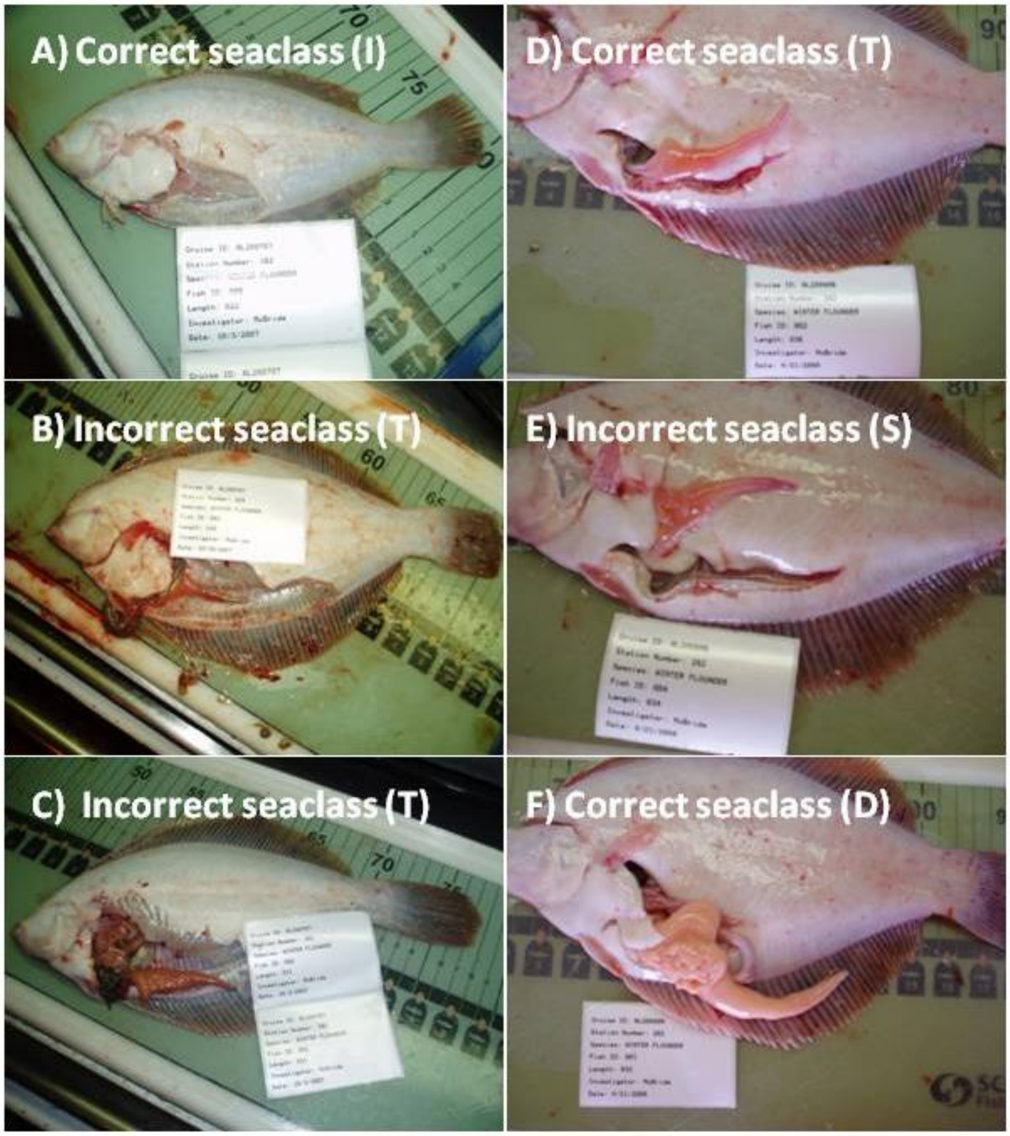


Figure 3. Images of dissected for winter flounder (*Pseudopleuronectes americanus*) females taken aboard NEFSC resource surveys. (A) An immature female collected in southern New England during October; this was correctly assigned at sea. (B) An immature female on Georges Bank in October; this was not correctly assigned at sea. (C) A first-time developing female collected in southern New England in October; this fish was preparing to spawn next spring – and was fairly well along – but it had not spawned before so it was immature. (D) A resting female collected on the Scotian Shelf in April; this was correctly assigned at sea. (E) A re-developing female collected on the Scotian Shelf in April; the gonad is not flaccid so it should not have been called spent, resting would have been correct because the partially-yolked eggs observed by histology are not apparent macroscopically. (F) A developing female collected on the Scotian Shelf in April; this was correctly assigned at sea.

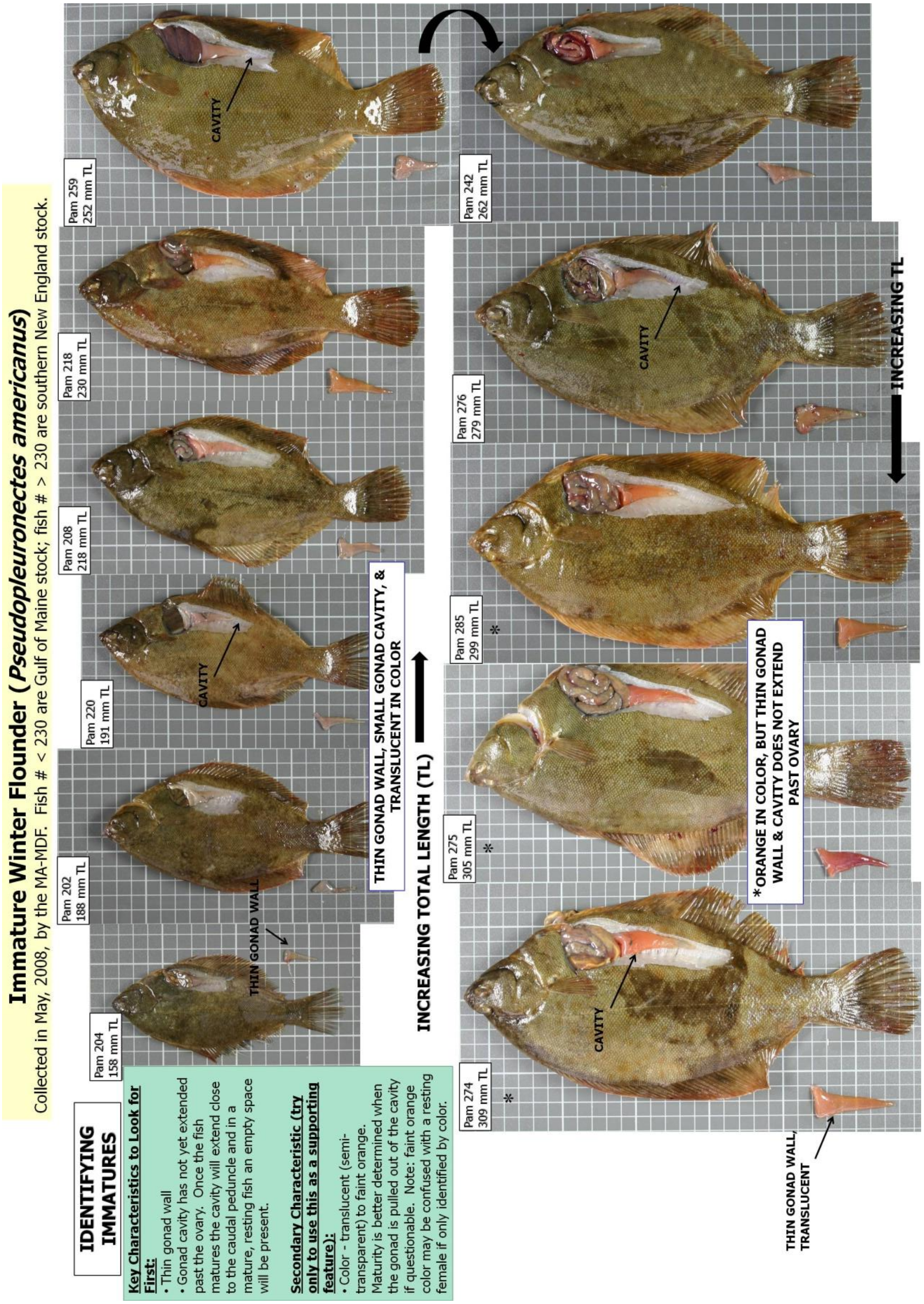


Figure 4. Sample training poster hung in the NEFSC main building cutting room in February, 2011.

Appendix Table 1

Female maturity staging criteria used during NEFSC bottom trawl surveys. Modified from Burnett et al. (1989).

Class	Code	Description and Criteria
Immature	I	Ovary paired, tube-like organ, small relative to body cavity; thin, transparent outer membrane; contains colorless to pink jell-like tissue with no visible eggs
Developing	D	Ovaries enlarge to occupy up to 2/3 of body cavity; if blood vessels present, they become prominent; ovary has granular appearance as yellow to orange yolked eggs develop
Ripe	R	Enlarged ovaries may fill entire body cavity; mixture of yellow to orange yolked eggs and hydrated or "clear" eggs present (50% or more clear eggs denotes ripe ovary, while less than 50% denotes developing ovary) *
Ripe & Running	U	Ripe female with eggs flowing from vent with little or no pressure to abdomen
Spent	S	Ovaries flaccid, sac-like, similar in size to ripe ovary; color red to purple; ovary wall thickening, becoming cloudy and translucent vs. transparent as in ripe ovary; some eggs, either clear or yolked, may still be present, however most adhere to ovary wall; therefore, CUT OPEN OVARY to make sure there is no mass of eggs in center of ovary (as in stages D and R)
Resting	T	Gonad reduced in size relative to ripe ovary, but larger than an immature; interior jell-like with no visible eggs **Flounders**: ovary does not appear to reduce in size relative to body cavity as much as in gadids, and interior usually yellow or orange; apparently, eggs spawned and after a short spent stage, ovary develops up again with yolked eggs which are small and do not get any larger until prior to next spawning season; ovary wall thicker and tougher than ripe ovary wall, and wall is cloudy or translucent, rather than clear as in ripe ovary

* This criterion (in paratheses) is no longer used. Any number of hydrated eggs classifies a fish as ripe, unless they freely flow from the vent, in which case the fish is running-ripe.

Appendix Table 2
Algorithm to assign maturity class to for winter flounder (*Pseudopleuronectes americanus*) females based on evaluation of gonad histology. The first algorithm is used to assign each fish to the standard, six-class scheme (A), the second algorithm is used to assign each fish to an expanded, ten-class scheme (B). Regardless, both schemes assign the same fish to immature versus mature classes when fitting maturity data to a logistic model.

(A)

```
* Assign the laboratory (histology) maturity assignments;

if (MAOS = 'CN' and POFs = 0) then labClass = 'I';

if MAOS = 'PG' then do;
 if POFs = 0 then do;
    if Tuni_thick = 1 then labClass = 'I';
    if Tuni_thick = 2 then labClass = 'T';
   end;
  if POFs > 0 then do;
 if POFage < 3 then labClass = 'S';
 if POFage > 2 then labClass = 'T';
end;
end;

if MAOS ='LC' then do;
 if POFs = 0 then do;
   if Tuni_thick = 1 then labClass = 'I';
   if Tuni_thick = 2 then labClass = 'T';
  end;
  if POFs > 0 then do;
 if POFage < 3 then labClass = 'S';
 if POFage > 2 then labClass = 'T';
end;
end;

if MAOS = 'V1' then do;
 if POFs = 0 then do;
   if Tuni_thick = 1 then labClass = 'I';
   if Tuni_thick = 2 then labClass = 'T';
  end;
 if POFs > 0 then labClass = 'T';
end;

if MAOS = 'V2' then labClass = 'D';

if MAOS = 'GM' then labClass = 'D';

if MAOS = 'B1' then do;
 if POFs = 0 then labClass = 'R';
  if POFs > 0 then labClass = 'U';
end;

if MAOS = 'B2' then do;
 if POFage < 2 then labClass = 'U';
  if POFage > 1 then labClass = 'S';
end;
```

Appendix Table 2 (cont.)

(B)

```
* a more complex subroutine to assign finer maturity scale;

if (MAOS = 'CN' and POFs = 0) then labCla22 = '0Im';

if season = 'FALL' then do;
 if MAOS = 'PG' then do;
  if Tuni_thick = 1 then labCla22 = '0Im';
   if Tuni_thick = 2 then labCla22 = '9Rx';
    if (POFs > 0 ) then labCla22 = '9Rx';
 end;
if MAOS = 'LC' then do;
 if Tuni_thick = 1 then labCla22 = '0Im';
  if Tuni_thick = 2 then labCla22 = '9Rx';
   if (POFs > 0 ) then labCla22 = '9Rx';
 end;
end;

if season = 'SPRING' then do;
if MAOS = 'PG' then do;
 if POFs = 0 then do;
  if Tuni_thick = 1 then labCla22 = '0Im';
   if Tuni_thick = 2 then labCla22 = '7Re';
  end;
if (POFs > 0 ) then do;
 if POFage < 3 then labCla22 = '6Sp';
  if POFage > 2 then labCla22 = '7Re';
 end;
end;
if MAOS = 'LC' then do;
 if POFs = 0 then do;
  if (Tuni_thick = 1 and Stroma ^= 2) then labCla22 = '1If';
  if (Tuni_thick = 2 and Stroma ^= 0) then labCla22 = '8Dr';
   end;
if POFs > 0 then do;
 if POFage < 3 then labCla22 = '6Sp';
  if POFage > 2 then labCla22 = '7Re';
  end;
 end;
end;

if MAOS = 'V1' then do;
 if POFs = 0 then do;
  if (Tuni_thick = 1) then labCla22 = '1If';
   if (Tuni_thick = 2) then labCla22 = '8Dr';
   end;
 if POFs > 0 then labCla22 = '7Re';
end;

if MAOS = 'V2' then labCla22 = '2De';

if MAOS = 'GM' then labCla22 = '3Dm';
```

Appendix Table 2 (cont.)

```
if MAOS = 'B1' then do;
 if POFs = 0 then labCla22 = '4Ri';
  if POFs > 0 then labCla22 = '5RR';
end;

if (MAOS = 'B2') then do;
 if POFage < 2 then labCla22 = '5RR';
 if POFage > 1 then labCla22 = '6Sp';
end;
```

SDWG Background WP#9b

May 2011

VMS Stock Apportionment

SDWG52 WP 9: Validating the stock apportionment of commercial fisheries landings using positional data from Vessel Monitoring Systems (VMS): Impacts on the winter flounder stock allocations

Michael C. Palmer and Susan E. Wigley

**Update of Palmer MC, Wigley SE. 2007. Validating the stock apportionment of commercial fisheries landings using positional data from Vessel Monitoring Systems (VMS). US Dept Commer, Northeast Fisheries Sci Cent Ref Doc. 07-22.*

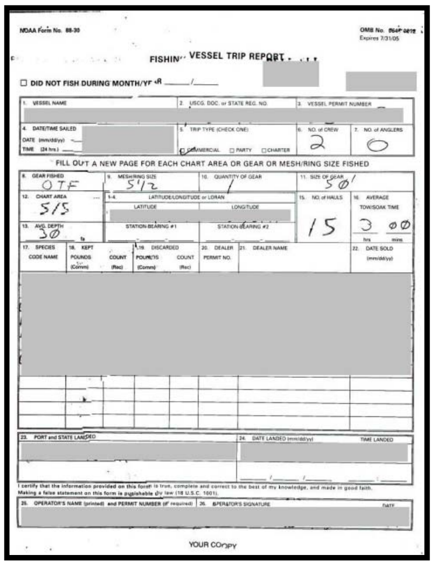
The Problem:

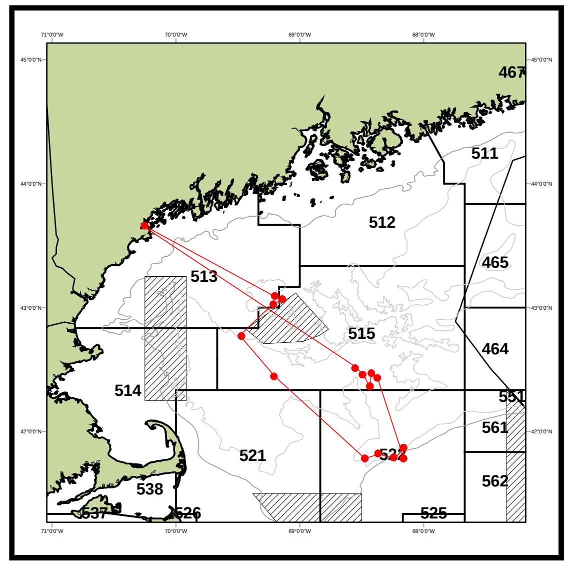
- Eight federally managed fish species are assessed as multiple stocks in Northeast Region.
    - Atlantic cod, haddock, yellowtail flounder, **winter flounder**, windowpane flounder, goosefish, silver hake, red hake.

- Commercial landings are assigned to stock areas using the statistical areas/positions reported on Vessel Trip Reports (VTRs).
    - Trip-level allocation; AA tables (Wigley et al., 2008)

The Problem (cont.):

- VTR misreporting has been previously identified as a problem (Palmer et al., 2007, A. Applegate and T. Nies 2007, Palmer and Wigley 2007).
    - Primarily, fishers under-report the number of statistical areas fished.





** Note: VTR and trip example shown are not from an actual trip. For illustration purposes only!*

- There is a need to assess the potential impacts of VTR misreporting on stock allocations.
    - Earlier studies have used relatively small subsets of the fishery (e.g., Study Fleet, vessels with observer coverage, etc.).
    - Updated the previous Palmer Wigley (2007) analysis to include years 2007and 2008.

Methodology:

- VMS coverage of landings is greater relative to observer data and available real-time.
    - Nearing census coverage in some fleet sectors (e.g., Atlantic scallop, NE groundfish,) as required by recent management measures (e.g., FW 17 Atlantic Scallop FMP, FW 42 NE Multispecies FMP).

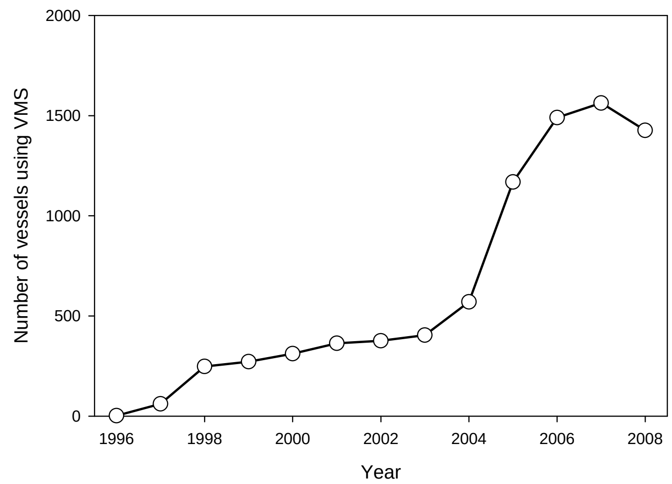


Figure 2

- VMS data have been used in other studies as a proxy for location of NE Region fishing activity (e.g., Murawski et al., 2005; Nies and Applegate, 2007).
    - Used average vessels speeds to categorize activity (e.g., < 3.5 knots = fishing)

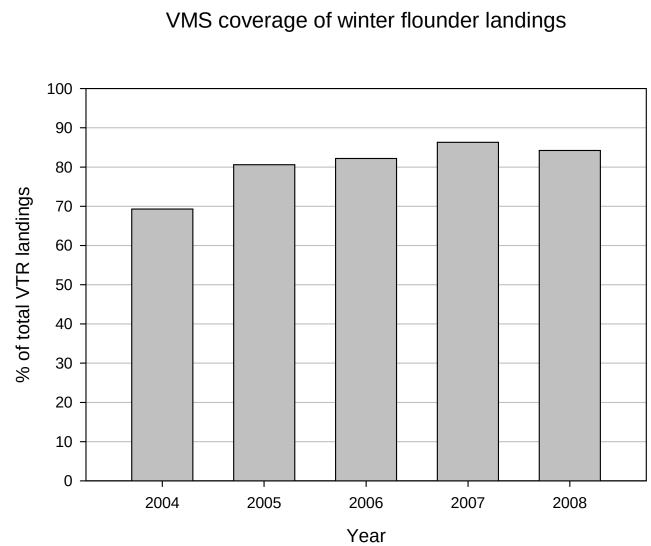
- Used positional information from Vessel Monitoring Systems (VMS) to:
    1. Assess the magnitude of VTR statistical misreporting; and,
    2. Assess the impacts of VTR statistical area misreporting on stock allocations.

Methodology (cont.):

- Examined calendar years 2004 to 2008.

- Included all vessels having reported landing one or more of the eight species and having fished with VTR gear codes of OTF, DRS, GNS and LLB.
    - Accounted for > 96 % of total VTR-reported landings for each of the eight species.

- Matched VTR trips to VMS data using permit number and date sail/land from VTR.
    - Matched trips accounted for 17.6 – 92.0 % of total VTR species landings.
        - **Since 2005 VMS has provided >80% coverage of winter flounder landings.**



Based on Table 11

Methodology (cont.):

- Used average vessel speed from VMS data to classify polled positions into either 'fishing' or 'non-fishing' activity.
- Calculated the statistical area fished from VMS fished positions → compared to VTR.
- Used a constant CPUE model to assign trip landings to stock area based on VMS-indicated locations of fishing activity → compared to VTR-based stock allocations.
- Validated the method against Northeast Fisheries Observer Program (NEFOP) data.

Methodology (cont.):

- Average vessel speed ranges by gear type:
  - **OTF** – fishing = 2.0 to 4.0 knots
    - Accuracy = 99.2 % correct for ‘fishing’, 31.8 % incorrect for ‘non-fishing’ – **overestimates fishing activity**.
  - **DRS** – fishing = 2.5 to 6.0 knots
    - Accuracy = 98.3 % correct for ‘fishing’, 69.3 % incorrect for ‘non-fishing’ – **overestimates fishing activity**.
  - **GNS** – fishing = 0.1 to 1.3 knots
  - **LLB** – fishing = 0.1 to 1.3 knots

Methodology (cont.):

- Constant CPUE allocation model: $\hat{L}_{sk} = \left(\left(\sum l_{si}\right) + l_{sk}\right) \bullet \left(\frac{t_k}{\left(\sum t_i\right) + t_k}\right)$

where:

$\hat{L}_{sk}$ = VMS prorated trip landings for species *s*, stock *k* (kg)

l_s = Trip landings for species *s* in stock area, *k*, as derived from VTR reports (kg)

l_i = Trip landings for species *s* in stock areas *i*, where $i \neq k$, as derived from VTR reports (kg)

t_k = Time spent fishing in stock area, *k*, as derived from VMS positional data (days)

t_i = Time spent fishing in stock area *i*, where $i \neq k$, as derived form VMS positional data (days)

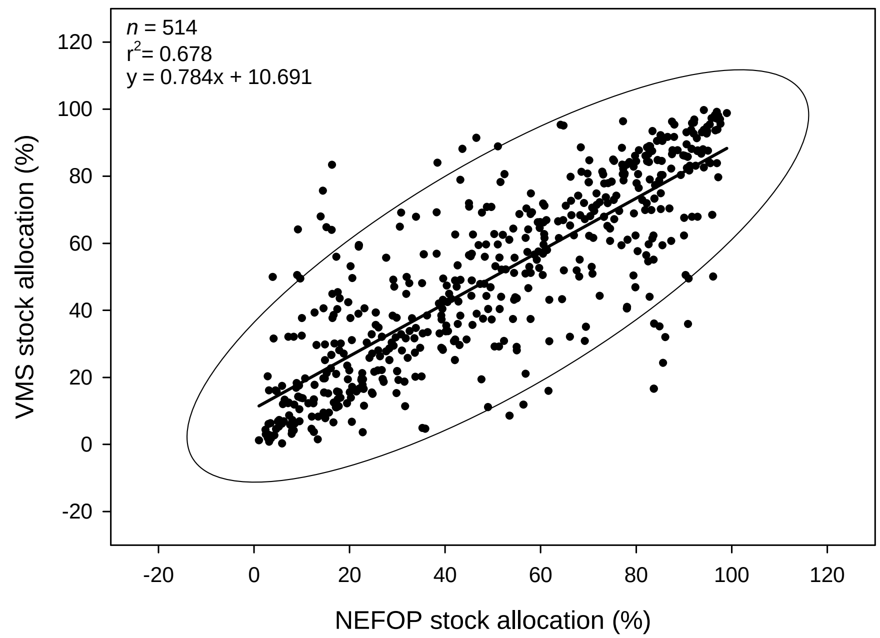


Figure 6

Methodology (cont.):

- Compare VTR statistical area fished to NEFOP data.
  - Accurate reporting for single area trips, underreporting of multi-area trips.

Year	Trip category	Number of trips	Agreement level	Number of trips	Percent of total category trips (%)
2004	Single area	135	Complete	129	95.6
			None	6	4.4
	Multi-area	114	Complete	6	5.3
			None	2	1.8
			Partial	106	93.0
2005	Single area	490	Complete	462	94.3
			None	27	5.5
			Partial	1	0.2
	Multi-area	411	Complete	57	13.9
			None	13	3.2
			Partial	341	83.0
2006	Single area	305	Complete	293	96.1
			None	10	3.3
			Partial	2	0.7
	Multi-area	209	Complete	35	16.7
			None	6	2.9
			Partial	168	80.4
2007	Single area	469	Complete	442	94.6
			None	27	5.4
	Multi-area	302	Complete	46	15.2
			None	9	3.0
			Partial	247	81.8
2008	Single area	385	Complete	367	95.3
			None	17	4.4
			Partial	1	0.3
			Complete	42	15.5

Table 4

Methodology (cont.):

- Compare VMS-determined statistical area fished to NEFOP data.
  - Tends to overestimate number of statistical areas fished, but shows improved gains for multi-area trips.

Year	Area category	Number of trips	Agreement level	Number of trips	Percent of total category trips (%)
2004	Single area	135	Complete	123	91.1
			Partial	12	8.9
	Multi-area	114	Complete	77	67.5
			Partial	37	32.5
2005	Single area	490	Complete	431	88.0
			None	1	0.2
			Partial	58	11.8
	Multi-area	411	Complete	306	74.5
			Partial	105	25.5
2006	Single area	306	Complete	274	89.5
			Partial	32	10.5
	Multi-area	208	Complete	149	71.6
			Partial	59	28.4
2007	Single area	469	Complete	437	93.2
			Partial	32	6.8
	Multi-area	302	Complete	227	75.2
			Partial	75	24.8
2008	Single area	385	Complete	350	90.9
			None	2	0.5
			Partial	33	8.5
	Multi-area	270	Complete	190	70.4
			Partial	80	29.6

Table 5

Results:

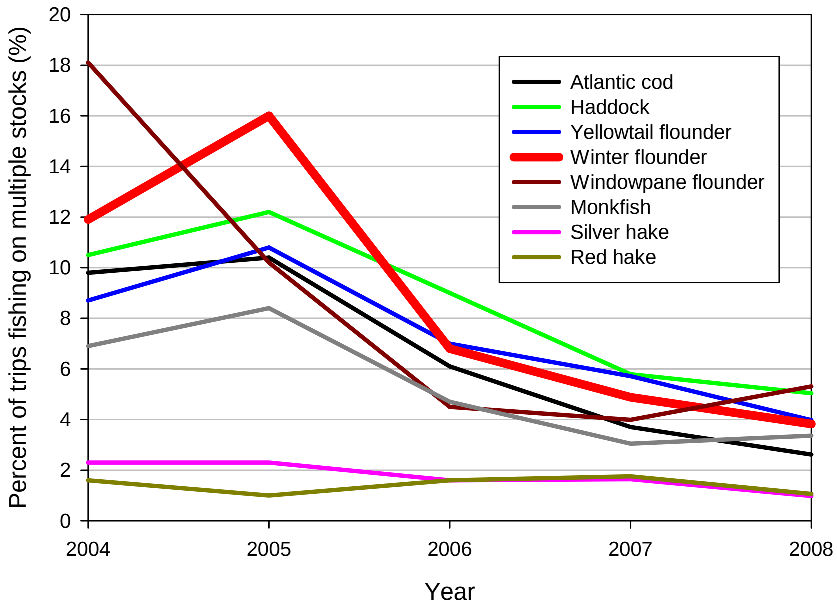
- For winter flounder, the VTR-based allocation has achieved stock allocations closer to NEFOP-based allocations compared to VMS-based methods in the most recent years.
  - **Note: stock allocations do not match actual stock allocations; allocations are contingent on observer coverage and availability of VMS data.*

Year	Stock area	NEFOP-based allocation	VTR-based allocation			VMS-based allocation		
		Stock allocation (%)	Stock allocation (%)	Difference	sum(abs(diff))	Stock allocation (%)	Difference	sum(abs(diff))
2004	GBK	89.1	82.7	-6.4	14.7	**90.3**	**1.2**	**2.3**
	GOM	3.1	2.2	-0.9		**2.3**	**-0.8**	
	SNEMA	7.7	15.1	7.4		**7.4**	**-0.3**	
2005	GBK	84.5	81.3	-3.2	6.4	**83.4**	**-1.1**	**3.0**
	GOM	1.7	4.1	2.4		**1.3**	**-0.4**	
	SNE	13.8	14.6	0.8		**15.3**	**1.5**	
2006	GBK	85.3	83.2	-2.1	4.6	**85.0**	**-0.3**	**1.0**
	GOM	1.6	1.4	-0.2		**1.4**	**-0.2**	
	SNEMA	13.1	15.4	2.3		**13.6**	**0.5**	
2007	GBK	72.7	**69.1**	**-3.7**	**8.3**	65.4	-7.3	**14.7**
	GOM	2.6	**2.1**	**-0.5**		3.4	0.8	
	SNEMA	24.6	**28.8**	**4.2**		31.2	6.5	
2008	GBK	84.6	**84.0**	**-0.6**	**3.0**	78.8	-5.8	**11.9**
	GOM	2.7	**1.8**	**-0.9**		2.6	-0.1	
	SNEMA	12.6	**14.1**	**1.5**		18.6	5.9	

From Tables 6-10

Results:

- Percentage of trips fishing on multiple stocks has declined over time.
  - Not clear whether this is caused by:
    1. A change in the types of trips included in the analytical set.
       - FW 42 (November 2006) required VMS for all limited access NE Multispecies vessels.
       - Prior to FW 42, VMS was only required when fishing in Special Management Programs (offshore).
    2. A true reduction in the frequency of multi-stock area trips.
  - Since 2005, VMS has consistently covered 80-87% of winter flounder landings.
    - VMS coverage has remained consistent since 2006, yet the percentage of multi-stock trips has declined.



Based on Table 18

Methodology (cont.):

- Compare VTR-determined statistical areas fished to VMS-determined statistical area fished for the larger VTR-VMS analytical set.
  - Level of misreporting/underreporting has remained consistent over time.

Year	Trip category	Number of trips	Agreement level	Number of trips	Percent of total category trips (%)
2004	Single area	2,895	Complete	2,688	92.8
			None	194	6.7
			Partial	13	0.4
	Multi-area	2,997	Complete	74	2.5
			None	139	4.6
			Partial	2,784	92.9
2005	Single area	5,630	Complete	5,267	93.6
			None	334	5.9
			Partial	29	0.5
	Multi-area	4,279	Complete	265	6.2
			None	206	4.8
			Partial	3,808	89.0
2006	Single area	13,488	Complete	12,869	95.4
			None	590	4.4
			Partial	29	0.2
	Multi-area	5,677	Complete	234	4.1
			None	221	3.9
			Partial	5,222	92.0
2007	Single area	19,917	Complete	19,104	95.9
			None	785	3.9
			Partial	28	0.1
	Multi-area	6,007	Complete	284	4.7
			None	234	3.9
			Partial	5,489	91.4
2008	Single area	16,797	Complete	16,124	96.0
			None	641	3.8
			Partial	32	0.2
	Multi-area	4,028	Complete	172	4.3
			None	170	4.2
			Partial	3,686	91.5

Table 17

Results:

- VTR and VMS-based allocation differences <5% in majority of years/stocks.
  - Predominance of large differences in recent 2 years, though this corresponds to the period when VTR-based methods appeared to outperform VMS-based methods.

Year	Total species landings (kg)	Stock area	VTR landings allocation (kg)	VMS landings allocation (kg)	Δ landings allocation abs(kg)	VTR stock allocation (%)	VMS Stock allocation (%)	Difference (%)	Relative difference (%)
2004	3,127,781	GBK	2,420,182	2,459,208	39,026	77.4	78.6	-1.2	-1.6
		GOM	94,235	95,648	1,413	3.0	3.1	0.0	0.0
		SNE	**613,364**	**572,925**	**40,439**	**19.6**	**18.3**	**1.3**	**6.6**
2005	2,800,638	GBK	1,976,251	1,985,963	9,712	70.6	70.9	-0.3	-0.4
		GOM	**132,155**	**112,737**	**19,418**	**4.7**	**4.0**	**0.7**	**14.9**
		SNE	692,232	701,939	9,707	24.7	25.1	-0.3	-1.2
2006	2,128,053	GBK	837,904	847,487	9,583	39.4	39.8	-0.5	-1.3
		GOM	151,351	151,497	146	7.1	7.1	0.0	0.0
		SNE	1,138,798	1,129,069	9,729	53.5	53.1	0.5	0.9
2007	2,172,096	**GBK**	**766,057**	**713,963**	**52,094**	**35.3**	**32.9**	**2.4**	**7.3**
		GOM	**193,425**	**204,320**	**10,895**	**8.9**	**9.4**	**-0.5**	**-5.3**
		SNE	1,212,614	1,253,813	41,199	55.8	57.7	-1.9	-3.3
2008	1,875,233	**GBK**	**915,033**	**849,254**	**65,779**	**48.8**	**45.3**	**3.5**	**7.7**
		GOM	187,557	193,399	5,843	10.0	10.3	-0.3	-3.0
		SNE	**772,643**	**832,579**	**59,936**	**41.2**	**44.4**	**-3.2**	**-7.2**

From Tables 20-24

Conclusions:

- In general VTR reporting of statistical areas is problematic - compliance needs to be improved.
  - Scope of the problem is manageable.
    - Of the approx. 2,500 vessels submitting VTRs annually, there are < 300 vessels which frequently under-report statistical areas on their VTRs.
- The impacts of VTR misreporting on the allocation of winter flounder landings are minor (< 5.0 % relative difference) in the majority of instances.
  - Can be significant for some stocks, particularly the smaller stocks.
- For winter flounder VTR misreporting/underreporting is not likely a large source of landings uncertainty; particularly in recent years.

Uncertainties:

- VMS determination of fishing activity – tends to overestimate fishing effort.
- Constant CPUE-model used to allocate landings to stock area violates known groundfish distribution patterns.
- VMS does not provide census coverage of the landings of the eight species examined.
  - For winter flounder, the coverage of the landings is high (>80%).

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VMS Stock Apportionment

Using positional data from vessel monitoring systems (VMS) to validate the logbook-reported area fished and the stock allocation of commercial fisheries landings, 2004-2008[1]

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Abstract

Vessel monitoring system (VMS) positional data from northeast United States fisheries were used to validate the statistical area fished and stock allocation of commercial landings derived from mandatory logbooks. A gear-specific speed algorithm was applied to VMS positions collected between 2004 and 2008 from the otter trawl, scallop dredge, sink gillnet and benthic longline fisheries to estimate the location of fishing activity. Estimated fishing locations were used to re-allocate the stock area landings of eight federally managed groundfish species. The accuracy of the VMS method relative to the mandatory logbooks was assessed using haul locations and catch data recorded by at-sea observers. VMS-based allocations generally outperformed VTR-based allocations; VMS methods achieved stock allocations more similar to observer-based allocations in 58 of the 90 cases examined (18 stocks over 5 years). The VMS algorithm tended to overestimate the number of statistical areas fished such that when a trip's fishing activity occurred in a single statistical area, logbooks more accurately reflected the true fishing location. On trips where fishing activity occurred in multiple statistical areas, the VMS algorithm showed appreciable gains relative to logbook data. VMS-based methods show promise as a means of validating the VTR-based allocations. However, given the limited extent of VMS both over time and in breadth of fisheries covered, it is not an acceptable surrogate for VTR-based allocations.

Introduction

Among the federally managed fish species in the northeast United States (U.S.), eight species are managed and assessed as two or more discrete stocks. The eight species are: Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), yellowtail flounder (*Limanda ferruginea*), winter flounder (*Pseudopleuronectes americanus*), windowpane flounder *(Scophthalmus aquosus*), goosefish (*Lophius americanus*), silver hake (*Merluccius bilinearis*) and red hake (*Urophycis chuss*). Stock units are comprised of statistical area groupings (Fig. 1) with stocks defined by divisions that, in most cases, relate to oceanographic features (e.g., Gulf of Maine, Georges Bank; Table 1). All of the species are managed under the Northeast Multispecies Fisheries Management Plan (NEFMC, 1985), with the exception of goosefish which is managed under the Monkfish Fisheries Management Plan (NEFMC, 1998).

In the northeast U.S., dealer weighout data are assumed to be a census of commercial landings amounts. Commercial landings are allocated to management stocks using the statistical areas reported on the mandatory paper logbooks (Wigley et al., 1998). These logbooks are referred to as vessel trip reports (VTRs). Current VTR regulations require that on completion of a fishing trip, a logbook report must be submitted which documents the total catch by species for each statistical area in which fishing occurred (Title 50 of the U.S. Congressional Federal Register, Part 648.7). Despite the regulations, it is known that misreporting of statistical area occurs, most frequently in the form of underreporting the number of statistical areas fished when fishing occurs in more than one area (Palmer et al., 2007; A. Applegate and T. Nies pers. comm.). While, underreporting of statistical areas does not necessarily translate to the misclassification of commercial landings to stock areas, the potential exists and the magnitude of these effects on the allocation of commercial landings is unknown.

The most reliable source of fisheries-dependent catch and effort data in the northeast U.S. are available from the information collected by at-sea fisheries observers. However, because these data are limited in their coverage (e.g., generally < 5% of all certain fisheries in a given year, Wigley et al., 2007) they cannot provide the synoptic coverage necessary to allocate commercial landings to stock area with any regularity. Vessel monitoring systems (VMS) in the northeast were first implemented for the limited-access scallop fisheries in 1998 (NEFMC, 1993). The use of VMS has increased over time (Fig. 2) and expanded to cover many fisheries (Table 2). Historically the larger off-shore vessels participating in the limited-access scallop and special-access groundfish fisheries were more likely to be equipped with VMS compared to the smaller near-shore vessels. With the passage of Framework 17 to the Atlantic sea scallop Fishery Management Plan (FMP; NEFMC, 2005) and Framework 42 to the Multispecies FMP (NEFMC, 2006), VMS is now required for a greater proportion of the smaller near-shore scallop and groundfish fleets. While VMS does not provide census coverage of these fleets, it does provide census coverage of trips taken by those vessels equipped with VMS. Given the increasing use of VMS in the region, this represents a potential tool to conduct large-scale validation of the statistical areas reported on VTRs.

Vessel positions obtained from VMS have been used as a proxy for the location of fishing effort in prior work (Deng et al., 2005; Murawski et al., 2005; Mills et al., 2007). Commonly, the average vessel speed is used to differentiate fishing activity from non fishing activity (Deng et al., 2005; Murawski et al., 2005). Many VMS programs do not require the transmission of instantaneous vessels speeds; only a vessel position and a date and time stamp. This has changed recently in some fisheries (Mills et al. 2007); however, most users of VMS data must infer vessel speed and course from averages calculated from successive positions. Northeast U.S. VMS regulations only require the transmission of the position and the associated date and time. Positions are typically collected once per 30 min from vessels participating in the limited access scallop fishery and once per 60 min from vessels participating in the groundfish fishery (Table 2). The classification error will also depend on whether the vessels speeds available to the analysis represent instantaneous vessels speeds or averaged vessels speeds calculated from the distance traveled between VMS polling events. As the VMS polling frequency increases, the relative accuracy of the calculated speeds decreases (Figure 3). The average vessel speed method can achieve accuracy levels as great as 99%, however it can also result in the incorrect classification of non-trawling activity (Mills et al., 2007) leading to an overestimation of fishing intensity. A more complex method utilizing both vessel speed and directionality has been attempted (Mills et al., 2007); however, this method did not improve the detection of fishing activity and reduced the inclusion of false positives only slightly (0.7%).

When using the vessel-speed method, the amount of classification error is sensitive to the VMS polling rate (Figure 3, Palmer, 2008), the speed ranges used to define fishing activity and the practices of the fishery under observation (e.g., how much overlap exists between the vessel-speed signals of fishing and non-fishing activity, how long are individual hauls). With the exception of Mills et al. (2007) much of the work so far published in the fisheries literature has utilized VMS data without a quantitative assessment of the classification error of fishing vs. non-fishing activity when the vessel-speed method is used. This paper assesses the ability of the VMS vessel-speed method to detect the statistical area fished and allocate fishery landings to stock area by comparing results to matching NEFOP trips. The method is then applied to assess VTR area reporting compliance and its impacts on the current VTR-based allocation method used in the northeast US.

Materials and methods

Data sources

VTR logbook trip, gear and species catch data were extracted from the VTR logbook reports from calendar years 2004 to 2008; prior to 2004, fewer than 500 vessels were equipped with VMS units in the Northeast Region, thus limiting the scope of a VMS-based allocation (Fig. 2). The analytical datasets were post-processed to remove any overlapping trips (i.e., trips taken by the same vessel with a date of sail occurring before the date of landing of a previous trip). Overlaps occur because of VTR reporting and/or data entry errors. This process resulted in the removal of between 1.2% and 2.2% of the total annual reported VTR trips from 2004 and 2008. Of the remaining trips, only those trips where at least one of the eight study species were reported as retained catch were retained in the dataset (Atlantic cod, haddock, yellowtail flounder, winter flounder, windowpane flounder, monkfish, silver hake, and red hake). Because the focus was on assessing the impact of statistical area misreporting on the proration of commercial landings, discards were not included in these analyses. All species weights were converted to live weight in kilograms (kg) using standard species conversion factors established by the Northeast Fisheries Science Center (NEFSC). The VTR dataset was further restricted to include only the four major gear types responsible for species landings in the region: fish bottom otter trawl (OTF), scallop dredge (DRS), sink gillnet (GNS) and benthic longline (LLB). VTR species landings were then assigned to a stock area based on the statistical area fished reported on the logbook (Palmer and Wigley, 2007; Table 1). The final VTR subsets used in this analysis contained between 32,000 and 34,000 trips per year (Table 3).

All available VMS data were extracted from the VMS database for each vessel and assigned to the appropriate VTR trip by matching on the vessel and assigning all VMS point locations with dates between the VTR date of sailing and date landed to the respective trip. The average vessel speed was calculated by dividing the haversine distance (Sinnott, 1984) by the time difference between consecutive VMS positions. All positions were assigned to a National Marine Fisheries Service (NMFS) statistical area (Fig. 1). Summaries of the number of VMS-VTR matched trips by year are included in Table 3.

In the northeast U.S., at-sea fisheries observers are coordinated by the NEFSC's Northeast Fisheries Observer Program (NEFOP). All NEFOP trips which could be matched to the list of VMS-VTR matched trips were extracted from the observer database. Matches were established using the vessel, date of sailing and date landed as reported on the VTR; trips with multiple matches were removed from the analyses. For all matched trips the associated haul duration, statistical area fished, species and retained catch weights were also extracted; retained catch weights were converted to live weight in kilograms (kg) using standard NEFSC conversion factors. Summaries of the number of matches by year are included in Table 3.

Method development and application

Past research using northeast U.S. VMS data have differentiated fishing activity from non-fishing activity by using only upper-speed bounds; < 3.5 knots for bottom trawl vessels (Murawski et al., 2005) and < 5.0 knots for scallop dredge vessels (Rago and McSherry, 2001). To our knowledge no attempt has been made to identify fishing activity from the VMS signals of fixed-gear vessels (i.e., sink gillnet, benthic longline). We attempted to improve vessel-speed classifications and extend the application to fixed-gear vessels through a combination of visual examination of the percent frequency distributions of VMS-derived average speeds, knowledge of fishing operations and observations from high-frequency polled GPS data.

Percent frequency distributions of VMS average vessel speed were plotted for all gear types (Fig. 4). These were then compared to percent frequency distributions of activity-specific (fishing vs. non-fishing) instantaneous vessel speeds from high-frequency polled GPS data (1 fix/10 seconds) collected from vessels involved in NMFS Cooperative Research projects (Fig. 5). These data sets included precise observations of the dates and times of fishing activity. Six trips taken by five separate vessels were analyzed; two groundfish bottom trawl trips, two scallop dredge trips and two gillnet trips. Individual vessel speed observations from all trips were combined by gear type and activity was classified as either 'fishing' or 'other'. For mobile gear, 'fishing' was defined as the period from winch brake lock to winch brake release; presumably the period when the gear is actually in contact with the bottom. For fixed gillnet gear, 'fishing' was defined as the period when gear is being hauled back. Unfortunately, high frequency polling data were not available for benthic longline activity. It is assumed that fixed gears such as sink gillnet and benthic longline gear are likely to be fished in very specific and limited geographic areas on a given trip, thus it is unlikely fishing is occurring on multiple fish stocks on a single trip. If this assumption is true, these analyses will not be as sensitive to misclassification of fixed gear activity relative to mobile gear activity.

VMS-based bottom otter trawl activity exhibits a very pronounced bi-modal distribution of vessel speeds. It was assumed that the first mode (2.8 knots) represented fishing activity and the second mode (8.0 knots) was indicative of steaming activity. Fishing activity falls within a very narrow range from approximately 2.0 to 5.0 knots as evidenced by the distributions observed from the high-frequency GPS data. A fishing speed window of 2.0 knots < fishing activity < 4.0 knots was used. This window fits the high-frequency polled GPS well, correctly classifying 99.2% of fishing activity. However, it also incorrectly categorizes 31.8% of non-fishing activity as fishing activity (Fig. 5). It is expected, that a portion of the non-fishing activity falling inside the window of fishing speed represents activity associated with the hauling and setting of the gear, which suggests that the impact of false-positives on statistical area fished estimation may not be as great as the 31.8% figure implies.

The VMS-based average-vessel-speed distribution of scallop dredge activity has a nearly tri-modal distribution (Fig. 4). Unlike bottom otter trawl speed distributions there is a high percentage of activity close to 0.0 knots. This may be indicative of shucking activity when vessels are drifting and allowing the crew to shuck scallops and clear the deck. The primary mode (4.2 knots) was assumed to represent fishing activity and the 8.2 knot mode was assumed to represent steaming activity. Scallop dredge fishing activity occurs over a broader range compared to trawl activity, falling between approximately 2 to 7 knots as evidenced by the distributions observed from the high-frequency GPS data (Fig. 5). A fishing speed window of 2.5 knots < fishing activity < 6.0 knots was used. This window fit the high-frequency polled GPS well, correctly classifying 98.3% of fishing activity; however, it incorrectly categorized 69.3% of non-fishing activity.

Like scallop dredge activity, VMS-observed sink gillnet average speed distributions have a tri-modal distribution (Fig. 4). Based on personal knowledge of gillnet operations, the first mode (0.6 knots) was interpreted as representing the hauling of gillnet gear, the second mode (3.0 knots) as re-setting the nets and the third mode (8.2 knots) as steaming activity. The majority of presumed hauling activity occurred between the speeds of 0.1 and 1.3 knots. This window did not fit the high-frequency polled GPS well. Only 50.0 % of the fishing activity was correctly identified. Conversely, this speed window incorrectly classified only 25.3% of non-fishing activity. Given the limited scope of the high frequency polling data (i.e., 2 trips taken by 1 vessel) and the likelihood that the geographic extent of fixed gear vessels is somewhat limited, a decision was made to use the 0.1 and 1.3 knot speed window.

Benthic longline average speed distributions have a bimodal distribution (Fig. 4). The first mode (0.8 knots) was interpreted as representing the hauling and setting of the longline gear and the second mode (10.0 knots) as steaming to and from the fishing grounds. For benthic longline gear the same speed used for gillnet gear was used (0.1 < fishing activity < 1.3 knots).

Those VMS locations identified as representative of fishing activity were then used to determine the statistical areas in which fishing occurred. Statistical areas fished were compared across data sources to assess whether the statistical areas derived from VMS-defined fishing activity represented an improvement over VTR reported statistical areas relative to NEFOP data. Trips were broken into two categories: single area trips (fishing occurs in only one statistical area per trip) and multi-area trips (fishing occurs in more than one statistical area per trip). Because all stock boundaries are divided along statistical area boundaries, correct reporting of multi-area trips are of the greatest concern. These are the trips having the potential to fish on multiple stocks of fish in a single trip and where misreporting of statistical area(s) may lead to incorrect estimates of stock removals. For each trip, the levels of agreement between the NEFOP, VMS and VTR statistical areas were categorized as in agreement ('Complete'), not in agreement ('None') or in partial agreement ('Partial'; at least one statistical area was in agreement, but not all). Agreement levels were contingent on agreement among both the number of statistical areas reported and the identity of those statistical areas. For example, if a VTR reports that fishing occurred in statistical areas 515 and 521 and VMS positions indicate that fishing occurred in 515 and 521 then the trip would be considered to be in agreement (‘Complete’). If the VTR reported fishing in 515, and the VMS data suggests fishing occurred in 515 and 521, then the trip would be considered to be in partial agreement (‘Partial’). If the VTR reported fishing in 515, and the VMS data suggests fishing occurred only in 521, then the trip would not be considered to be in agreement (‘None’). The same analysis was repeated on the larger set of VMS and VTR matched trips.

A VMS-based allocation algorithm was devised using the statistical areas fished from the VMS data to re-allocate VTR-reported landings to stock area. Fishing activity was assigned to stock area based on the species landed and statistical area in which the fishing activity was occurring. The time spent fishing in each stock area was estimated as the sum of fishing activity blocks occurring in each stock area. The duration of one activity block is contingent on the VMS polling frequency which is variable, but generally once per 30 minutes for scallop vessels and once per hour for groundfish vessels. Total VTR trip landings for each species (*s*) were allocated to stock area (*k*) based on the ratio of time spent fishing in each stock area as determined from VMS locations (Equation 1).

$$(1) \qquad \hat{L}_{sk} = \left(\left(\sum l_{si}\right) + l_{sk}\right) \bullet \left(\frac{t_k}{\left(\sum t_i\right) + t_k}\right)$$

where:

$\hat{L}_{sk}$ = VMS prorated trip landings for species *s*, stock *k* (kg)

l_s = trip landings for species *s* in stock area, *k*, as derived from VTR reports (kg)

l_i = trip landings for species *s* in stock areas *i*, where $i \neq k$, as derived from VTR reports (kg)

t_k = time spent fishing in stock area, *k*, as derived from VMS positional data (days)

t_i = time spent fishing in stock area *i*, where $i \neq k$, as derived form VMS positional data (days)

The results of the VMS-based allocation were compared to landings allocation derived from both NEFOP and VTR data sources to assess the relative accuracy of the VTR-based allocation and determine if the VMS-based algorithm resulted in improved estimates of landings by stock area. VTR and NEFOP species landings were prorated by assigning landings to stock area based on the reported statistical area. All comparisons were performed through an examination of the percent allocation to stock area as opposed to absolute landings because percent allocations derived from the traditional VTR source are used to allocate the amounts of commercial landings as determined through dealer weighout data (Wigley et al., 1998). The same analysis was performed on the larger VMS-VTR matched data set.

The VMS-based allocation method assumes a constant species catch-per-unit-effort (CPUE) at all fishing locations (i.e., species catch is distributed only as a function of the time spent fishing in each stock area). This assumption neglects species habitat preferences (e.g., sediment composition, water depth and temperature, etc.) which would result in species being more likely to be caught in some locales and not others. To assess the degree to which this assumption was violated, individual species trip allocations from the VMS-method were compared to the same allocations as determined from NEFOP observations using linear regression.

Results

Method validation using NEFOP data

Statistical area agreement between NEFOP and VTR was > 94% for single area trips across all years between 2004 and 2008, but less than 17% for multi-area trips (Table 4). Nearly all disagreements among the 'partial' multi-area trips matches (> 98%) are due to under-reporting of statistical areas (fewer statistical areas reported on the VTR compared to NEFOP); 105 trips in 2004, 337 in 2005, 166 in 2006, 247 in 2007 and 219 in 2008. There was a general trend towards improved VTR reporting of multi-area trips between 2004 and 2006, though the level of accurate reporting has remained constant at approximately 15% since 2007. Given the small sample size, limited number of years of NEFOP comparisons and potential for observer-type effects on VTR-reporting, caution should be taken in inferring any meaningful conclusion based on these apparent trends.

The statistical area agreement between NEFOP and VMS-based statistical areas was lower (≥ 88.0%) for single-area trips compared to the NEFOP-VTR comparisons (Table 5). The cause of disagreement among single-area trips is primarily due to the overestimation of statistical areas fished by the VMS-based method. The overestimation results from the VMS-based method misclassifying non-fishing activity as fishing activity. Agreement among multi-area trips is greater (> 67%) when using the VMS-method compared to the VTR-reported statistical area trips, with no complete disagreement among any of the trips. Among statistical areas in partial agreement there was a tendency for the VMS-method to overestimate the number of statistical areas fished (59.5% of partial matches in 2004, 53.3% in 2005, 50.8% in 2006, 57.3% in 2007, and 56.3% in 2008). The performance of the VMS-based method in detecting statistical areas fished is not equivalent for all gear types; a closer examination of the VMS-NEFOP statistical area comparison in 2005 showed that 80.3% (535 of 666) of trawl trips, 65.4% (17 of 26) of dredge trips, 83.8% (88 of 105) of gillnet trips and 97.1% (101 of 104) of longline trips have agreement levels of ‘Complete’. This finding supports the assumption that the misclassification of the location of fixed gear fishing activity is less likely compared to mobile gear activity.

The VMS-based allocation method arrived at annual stock allocations closer to NEFOP allocations relative to the VTR-based allocations for 58 of the 90 stock comparisons examined (eighteen stocks over five years; Tables 6 – 10). There were no species allocations for which the VMS-based allocation under-performed the VTR allocation in all five years. There was a general improvement in the VMS-based allocation between 2004 and 2006 with the number of species for which it under-performed the VTR allocation decreasing from three in 2004 to only one in 2006. However, the VMS method did not outperform the VTR method in 2007 and only marginally better in 2008. Of all species, goosefish, silver hake and red hake had the greatest percent difference relative to the NEFOP allocation. Comparisons of the individual trip stock allocations between the VMS-based method and NEFOP allocation showed strong agreement between VMS and NEFOP stock allocations ($r = 0.823$, $p < 0.001$, $n=514$; Fig. 6), however there was considerable spread in residuals. There are large differences in the NEFOP landings compared to VTR landings shown in Tables 6 – 10 for some species, most notably monkfish (e.g., in 2004 NEFOP estimated 380 mt compared to the VTR estimate of 71 mt). The exact reasons for these discrepancies are unknown, however there is a tendency for self-reported hail weights to be biased low (Palmer et al., 2007). Additionally, monkfish tails constitute a large proportion of monkfish landings and these are often incorrectly reported on VTRs as whole monkfish (Palmer et al., 2007). A conversion factor of 3.32 is applied to monkfish tail landings to convert these to whole weights; incorrect reporting of monkfish tails as whole monkfish will results in the underestimation of VTR monkfish landings by approximately a factor of 3.

Extrapolation to larger VMS-VTR matched dataset

The NEFOP-VMS-VTR subset of data used to validate the VMS-based method is relatively small compared to the total population of VTR-recorded trips (Table 3). The validation results suggest that for some trips monitored through VMS, the VMS-based allocation method can be used to gauge the accuracy of the stock allocations as determined through VTR reports. The VMS-VTR matched set is a much larger dataset. The subset of VTR reports examined (eight species caught using the four gear types) account for only approximately a quarter of the total VTR reports in a given year (Table 3), however this dataset accounts for greater than 95% of the landings of all the study species across the time series (Table 11). Similarly, VMS coverage is available for only 5,892 to 19,165 of the VTR trips in a given year (Table 3), but these trips account for 17.6 to 98.1% of the total landings of individual species (Table 11). By 2006, VMS data were available for trips responsible for landing greater than 70% of all species but goosefish; coverage of goosefish landings is low because there are no specific VMS requirements for the goosefish fishery (Table 2). In 2008 there was a slight decline in the number of vessels covered by VMS (Fig. 2), which appears to have led to a decrease in the percentage of landings covered by VMS.

All demersal species examined in this analysis are primarily caught by the otter trawl fishery except goosefish where gillnet gear is responsible for the majority of the landings. Gillnet is the secondary gear type for all species with the exception of haddock and silver hake which are secondarily targeted by benthic longline (Tables 12 -16). VMS coverage of the landings by most gear types is highly variable, though generally increasing with time; there is a general pattern of low gillnet coverage for landings of most species during the time series.

Examination of the VTR statistical area reporting using VMS-based statistical areas fished showed similar patterns to those observed in the NEFOP-VMS-VTR comparisons. Agreement levels of single-area trips exceeded 92% in all years and was always less than 6.5% for multi-area trips (Table 17). This level of agreement is less than that observed in the NEFOP-VTR comparison. It is unclear whether these lower rates of agreement are due to the overestimation of the number of statistical areas fished by the VMS method, an observer-effect, or some other factor. Closer examination of the partial matches revealed that the number of vessels apparently under-reporting the number of statistical areas fished was 397 in 2004, 477 in 2005 and 629 in 2006. Those vessels that likely frequently under-report trips (> 5 trips in a year) are responsible for the majority of the potentially under-reported trips. In 2004 there were

179 vessels that appeared to frequently under-report accounting for 1,876 of 2,797 of partial agreement trips (67.1%). In 2005, there were 221 vessels in this category, accounting for 2,787 of the 3,837 partial agreement trips (72.6%) and in 2006 there were 268 vessels which potentially under-reported the number of areas fished, accounting for 3,815 of the 5,251 partial agreement trips (72.7%). The number of vessels in this category increased in 2007 to 307 vessels accounting for 4,485 of the 5,489 partial agreement trips (81.7%) before falling in 2008 to 199 vessels accounting for 2,747 of 3,686 partial agreement trips (74.5%).

It is important to consider the implications of the matched trip set composition when interpreting the performance of the VMS-based method. The performance relative to the VTR method is contingent on the number of multi-area trips and the gear composition of the matched data set. For example; a higher proportion of multi-area trips in the examined dataset would appear to improve the performance of the method. The percentage of multi-stock trips recorded by VMS increased in 2005 followed by a decline in 2006 to levels below 2004 values for all but windowpane, silver hake and red hake trips (Table 18). The declines generally continued in 2007 and 2008, with only 1 species (windowpane flounder) having > 5% of trips fishing on multi-stock trips by 2008. Those trips fishing on multiple stocks are predominantly (≥ 99.0%) mobile-gear vessels (Table 19), implying that fixed-gear fishing effort occurs primarily in localized geographic areas such that landings from fixed-gear trips are unlikely to have come from multiple stocks. This supports the prior assumption that the misinterpretation of the VMS speed signals from fixed-gear trips is unlikely to result in the misallocation of landings.

The perceived under-reporting of statistical areas in the VTR data led to minor (< 5%) differences in the overall species allocations; only nine stocks in the five year time-series exhibited differences in stock allocations exceeding 2.0% (2004: northern and southern silver hake, ± 3.0%; 2006: northern and southern windowpane flounder, ± 4.7%; 2007: Georges Bank winter flounder, 2.4%; 2008: Georges Bank winter flounder, 2.4%, southern New England winter flounder, -3.2%, and northern and southern windowpane flounder, ± 3.4%; Tables 20 – 24). These figures are similar to the total proportion of species landings potentially misallocated, which was < 5% for all species-years examined; again with the exception of 2004 silver hake, 2006 and 2008 windowpane flounder, and 2008 winter flounder. However, these small differences in percent allocation have a disproportionate effect on the less abundant stock such as such as Gulf of Maine haddock, southern New England yellowtail, southern windowpane and northern silver hake. For these, stocks, minor differences can be large (≥ 5.0%) relative to the percent of the total species landings allocated to that stock (Tables 20 – 24). These impacts are most notable in the stock allocations of the southern New England/mid-Atlantic yellowtail flounder. Stock allocation differences between the VTR and VMS methods were ≤ 1.6% for all years, however commercial landings of this stock were ≤ 6.4% of the total stock landings as estimated from the VTR reports resulting in relative differences of 53.8, 61.9 and 25.0% for the years 2004, 2005 and 2006 respectively. In 2007 and 2008 the relative differences were < 2%. Of the 90 stock/year combinations analyzed the VMS-based method stock allocations had ≥ 5.0% relative difference compared to the VTR-based allocations for 25 of the comparisons.

There was a tendency for the VTR-method to over-allocate the predominant Atlantic cod and haddock stocks (i.e., Georges Bank) relative to the VMS method (2004 haddock was an exception). There were no consistent trends in the over/under-allocation of Georges Bank yellowtail and winter flounder stocks and under/over-allocate the Gulf of Maine and southern New England stocks. The direction of stock allocation differences for goosefish, windowpane flounder, silver hake and red hake was variable from year to year.

Discussion

The underreporting of statistical areas on VTR logbooks is a problem that affects greater than 80% of the multi-area trips examined. The VTR underreporting rates from this study agree closely with past studies that have used both NEFOP and haul-by-haul self reported data (Palmer et al., 2007). While the impacts of this underreporting are relatively small in regards to overall stock allocation percentages, the relative impacts on less abundant stocks such as southern New England/mid-Atlantic yellowtail can be substantial. This is in agreement with the findings of other studies that have examined this issue using more restrictive data sets (A. Applegate and T. Nies pers. comm.). These discrepancies have implications on the estimation of fishery removals and the assessment of these stocks. While the impacts are minimal for the majority of stocks examined, the extent of the impacts on those few stocks that are significantly affected (e.g., southern New England yellowtail flounder) suggests that this is a problem deserving of attention.

Many of the stock assessments of these eight species use finer stratification of commercial landings (e.g., quarter and market category) to estimate landings at age numbers used in virtual population analysis (VPA), or similar assessment models (Mayo and Terceiro, 2005). This paper does not consider the impacts of statistical area reporting patterns on these finer scale stratifications of commercial landings, however the accuracy of finer-scale allocations would be sensitive to the number of multi-area trips included in each strata. It is possible that the effects of statistical area mis-reporting on stock allocations are reduced due to offsetting errors (i.e., a trip that misallocates 1,100 kg to the Georges Bank cod stock would be largely offset by a trip that misallocates 1,200 kg to the Gulf of Maine cod stock). However, the spatial accuracy of VTR reports is critical not only for the assessment of fish species, but also of protected species such as sea turtles (e.g., Murray, 2004, 2005, 2006; Orphanides and Bisak, 2006) and marine mammals (Belden et al., 2006). When these data are used at finer spatial scales the accuracy of VTR reports becomes increasingly important.

It is important to consider that the results of these analyses apply only to the trips monitored by VMS; however by 2006, trips responsible for more than 70% of the species landings examined were monitored by VMS (Table 11). VMS coverage of some fisheries such as the Northeast multispecies complex is nearing a census, with all vessels required to use a VMS unit when fishing on a Multispecies Days-At-Sea (DAS) (NEFMC, 2010). The increased coverage improves the utility of VMS data as a validation tool for managers and as a data set of spatial fishing patterns for analysts. The number of vessels responsible for the landings of the eight species examined has remained constant at slightly less than 1,200 (Table 3), however the number of these vessels monitored by VMS has increased from 38.5% (453 of 1,176) in 2004 to 86.8% (957 of 1,102) by 2007. The increase in VMS usage appears to have occurred primarily among the smaller-nearshore fleet in response to VMS requirements to participate in the general category scallop fishery (NEFMC, 2005) and the NE multispecies fishery (NEFMC, 2006) as indicated by the drop in percentage of multi-stock area trips recorded by VMS from 2004 to 2008 (Table 13). There was a decrease in the number of multiple stock area trips from 2005 to 2008 which may explain the improved performance of VTR-based allocations in 2007 and 2008 (Tables 9 and 10).

The results are sensitive to the accuracy of average VMS vessel-speeds in differentiating fishing activity from non-fishing activity as well as the validity of the VMS-based allocation. This study defines fishing activity using narrower speed ranges than have been used in past studies which should lead to more conservative estimates of fishing effort. The speed range used for the mobile gears agree closely with the speeds obtained from high-frequency polling of vessels GPS units suggesting that these ranges are reasonable. The speed ranges used for gillnet gear did not correspond all that well with the high frequency GPS polling data; however, given the low percentage of fixed gear trips fishing on multiple stock areas (Table 19), the lack of agreement should not negatively impact these analyses. Additionally, this study relied on average vessel speeds not instantaneous vessel speeds, which are more analogous to the speeds estimated from high-frequency GPS polling. The averaging process blurs activity from observation to observation, potentially leading to an incorrect determination of fishing activity (Fig. 3; Deng et al., 2005; Palmer, 2008). These impacts were not explicitly considered in this study and represent an area of uncertainty.

The speed ranges adequately classify fishing activity (> 98% success for mobile gear, ≥ 50% success for gillnet gear), but tend to overestimate the amount of fishing by incorrectly classifying non-fishing effort as fishing (69.3% misclassification of non-fishing scallop activity). The overestimation was apparent in the comparisons of statistical areas fished between VMS and NEFOP data (Table 5). Future work should focus on the use of more advanced statistical procedures such as mixture distribution models (e.g., Marin et al., 2005) to decompose the mixed distributions of vessels speed. The fine scale observations taken from cooperative research vessels could be used identify likely parameterization of the underlying probability density functions.

VMS data indicate where it is likely that fishing effort is occurring but provide no information on catch composition. A critical assumption of the VMS-based allocation is that the proportion of species caught across multiple stock areas on a fishing trip is only a function of the time spent fishing in each stock area. In the Gulf of Mexico penaeid shrimp fishery, this assumption has generally held true (Cole et al., 2006), however, it may not be appropriate in a multispecies groundfish fishery where the species habitat preference is variable and the target species changes from trip to trip. While the relationship between VMS and NEFOP allocations was significant suggesting that an assumption of constant CPUE is valid, there was a considerable amount of variability (Fig. 6). However, the use of groundfish habitat models (e.g., Rooper et al., 2005) could be used to improve the catch allocation used in this paper. The large degree of variability in this relationship is not independent of overestimating the time spent in an area by the VMS method; disproportionate overestimation of time spent fishing in a particular stock area will have a direct affect on the VMS-based allocation.

The various uncertainties and shortcomings of the VMS allocation method point out that this is not a replacement for a VTR-based allocation. Additionally, the low vessel coverage of historical VMS data (Fig. 2) limits its use as a tool to correct historical misreporting. However, the results do show that VMS data can be used as a tool to monitor the accuracy and completeness of VTRs and guide efforts to improve VTR compliance. The number of vessels which are potentially under-reporting statistical areas on a frequent basis is small (< 350 vessels) relative to the total number of vessels submitting VTRs (> 2,000; Table 3). Improvements are needed in the compliance of VTR reporting regulations, particularly among those vessels likely to be fishing on multiple fish stocks. Given the manageable size of the problem and availability of tools to monitor these data, the quality of self-reported data should be monitored and improved through targeted outreach and education activities.

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Tables

Table 1. Statistical areas used to define species stock units for eight species examined.

Species	Stock area	Statistical areas
Atlantic cod (*Gadus morhua*)	Georges Bank (GBK)	521, 522, 525, 526, 533, 534, 537 - 539, 541 - 543, 551, 552, 561, 562, 611 - 616, 621 - 629, 631 - 639
	Gulf of Maine (GOM)	464, 465, 467, 511 - 515
Haddock (*Melanogrammus aeglefinus*)	Georges Bank (GBK)	521, 522, 525, 526, 533, 534, 537 - 539, 541 - 543, 551, 552, 561, 562, 611 - 616, 621 - 629, 631 - 639
	Gulf of Maine (GOM)	464, 465, 467, 511 - 515
Yellowtail flounder (*Limanda ferruginea*)	Georges Bank (GBK)	522, 525, 551, 552, 561, 562
	Cape Cod/Gulf of Maine (GOM)	464, 465, 467, 511, 512, 513, 514, 515, 521
	Southern New England/ Mid-Atlantic (SNE)	526, 533, 534, 537 - 539, 541 - 543, 611 - 616, 621 - 629, 631 - 639
Winter flounder (*Pseudopleuronectes americanus*)	Georges Bank (GBK)	522, 525, 551, 552, 561, 562
	Gulf of Maine (GOM)	464, 465, 467, 511, 512, 513, 514, 515
	Southern New England/ Mid-Atlantic (SNE)	521, 526, 533, 534, 537 - 539, 541 - 543, 611 - 616, 621 - 629, 631 - 639
Windowpane flounder (*Scophthalmus aquosus*)	North (NOR)	464, 465, 467, 511 - 515, 521, 522, 525, 542, 543, 551, 552, 561, 562
	South (SOU)	526, 533, 534, 537 - 539, 541, 611 - 616, 621 - 629, 631 - 639
Goosefish (*Lophius americanus*)	North (NOR)	464, 465, 467, 511 - 515, 521, 522, 551, 561
	South (SOU)	525, 526, 533, 534, 537 - 539, 541 - 543, 552, 562, 611 - 616, 621 - 629, 631 - 639
Silver hake (*Merluccius bilinearis*)	North (NOR)	464, 465, 467, 511 - 515, 521, 522, 551, 561
	South (SOU)	525, 526, 533, 534, 537 - 539, 541 - 543, 552, 562, 611 - 616, 621 - 629, 631 - 639
Red hake (*Urophycis chuss*)	North (NOR)	464, 465, 467, 511 - 515, 521, 522, 551, 561
	South (SOU)	525, 526, 533, 534, 537 - 539, 541 - 543, 552, 562, 611 - 616, 621 - 629, 631 - 639

Table 2. Fishery management plan (FMP) actions passed by the Northeast Fisheries Management Council (NEFMC) and Mid-Atlantic Fisheries Management Council (MAFMC) affecting the use of Vessel Monitoring System (VMS) in the northeast United States through December 31, 2006. Note: if a vessel is subject to VMS regulations from multiple programs, the most restrictive regulation applies.

Date effective	Fishery	Measure	Description	Reference
May 1998	Atlantic scallop	Amendment 4	Required VMS for all limited access full- and part-time vessels (hourly polling). **Note: Amendment 4 effective March 1994, but VMS implementation delayed by NMFS until May 1998.*	NEFMC 1993
May 1999	Atlantic herring	Original FMP	Required VMS for all category 1 vessels (hourly polling).	NEFMC 1999
May 2001	Atlantic scallop	Framework Adjustment 14	Required VMS for all limited access occasional-category vessels when participating in area access programs (half-hourly polling).	NEFMC 2001
May 2004	Northeast multispecies	Amendment 13	Required VMS for all vessels accessing the US/Canada shared resource area (half-hour polling within US/Canada area, hourly polling outside).	NEFMC 2003
November 2004	Atlantic scallop	Framework Adjustment 16	Required VMS for all general category vessels participating in area access programs (half-hour polling).	NEFMC 2004a
November 2004	Northeast multispecies	Framework Adjustment 40A	Required VMS for all vessels participating in special access programs (SAP) and when fishing under the Regular B Days-at-Sea (DAS) Program (hourly polling).	NEFMC 2004b
October 2005	Atlantic scallop	Framework Adjustment 17	Required VMS for all general category vessels landing > 40 lb scallop meats (half-hour polling).	NEFMC 2005
November 2006	Northeast multispecies	Framework Adjustment 42	Required VMS for all limited access NE multispecies DAS vessels using multispecies DAS (hourly polling).	NEFMC 2006
May 2010	Northeast multispecies	Amendment 16	Required VMS for all limited access NE multispecies DAS vessels using multispecies DAS or on a sector trip (hourly polling).	NEFMC 2010

Table 3. Summary of the Vessel Trip Report (VTR), Vessel Monitoring System (VMS), and Northeast Fisheries Observer Program (NEFOP) 2004 to 2008 data sets, by number of trips and number of vessels.

Year	Category	Number of trips	Number of Vessels
2004	VTR dataset	114,491	2,629
	VTR subset	32,272	1,176
	VMS-VTR matched set	5,892	453
	NEFOP-VMS-VTR matched set	249	150
2005	VTR dataset	121,442	2,599
	VTR subset	33,090	1,161
	VMS-VTR matched set	9,909	622
	NEFOP-VMS-VTR matched set	901	252
2006	VTR dataset	118,548	2,497
	VTR subset	32,431	1,155
	VMS-VTR matched set	19,165	886
	NEFOP-VMS-VTR matched set	514	255
2007	VTR dataset	112,902	2,404
	VTR subset	33,288	1,102
	VMS-VTR matched set	25,924	957
	NEFOP-VMS-VTR matched set	771	328
2008	VTR dataset	105,352	2,271
	VTR subset	33,645	1,064
	VMS-VTR matched set	20,825	845
	NEFOP-VMS-VTR matched set	655	316

Table 4. Summary of the agreement levels between statistical areas fished recorded by the Northeast Fisheries Observer Program (NEFOP) and the statistical areas fished reported on Vessel Trip Reports (VTR) from matched fishing trips from 2004 to 2006. Trip subcategories are based on the NEFOP-reported number of statistical areas fished. **Note: percentages may not sum to 100 due to rounding.*

Year	Trip category	Number of trips	Agreement level	Number of trips	Percent of total category trips (%)
2004	Single area	135	Complete	129	95.6
			None	6	4.4
	Multi-area	114	Complete	6	5.3
			None	2	1.8
			Partial	106	93.0
2005	Single area	490	Complete	462	94.3
			None	27	5.5
			Partial	1	0.2
	Multi-area	411	Complete	57	13.9
			None	13	3.2
			Partial	341	83.0
2006	Single area	305	Complete	293	96.1
			None	10	3.3
			Partial	2	0.7
	Multi-area	209	Complete	35	16.7
			None	6	2.9
			Partial	168	80.4
2007	Single area	469	Complete	442	94.6
			None	27	5.4
	Multi-area	302	Complete	46	15.2
			None	9	3.0
			Partial	247	81.8
2008	Single area	385	Complete	367	95.3
			None	17	4.4
			Partial	1	0.3
	Multi-area	270	Complete	42	15.5
			None	5	1.9
			Partial	223	82.6

Table 5. Summary of the agreement levels between statistical areas fished recorded by the Northeast Fisheries Observer Program (NEFOP) and the statistical areas fished as determined using Vessel Monitoring System (VMS) positional data from matched fishing trips from 2004 to 2006. Trip subcategories are based on the NEFOP-reported number of statistical areas fished. **Note: percentages may not sum to 100 due to rounding.*

Year	Area category	Number of trips	Agreement level	Number of trips	Percent of total category trips (%)
2004	Single area	135	Complete	123	91.1
			Partial	12	8.9
	Multi-area	114	Complete	77	67.5
			Partial	37	32.5
2005	Single area	490	Complete	431	88.0
			None	1	0.2
			Partial	58	11.8
	Multi-area	411	Complete	306	74.5
			Partial	105	25.5
2006	Single area	306	Complete	274	89.5
			Partial	32	10.5
	Multi-area	208	Complete	149	71.6
			Partial	59	28.4
2007	Single area	469	Complete	437	93.2
			Partial	32	6.8
	Multi-area	302	Complete	227	75.2
			Partial	75	24.8
2008	Single area	385	Complete	350	90.9
			None	2	0.5
			Partial	33	8.5
	Multi-area	270	Complete	190	70.4
			Partial	80	29.6

Table 6. Comparison of the Northeast Fisheries Observer Program (NEFOP), Vessel Trip Reports (VTR), and Vessel Monitoring System (VMS) stock allocations of 2004 commercial landings based on 249 matched trips. Bold text is used to indicate which method, VTR or VMS, achieve results closest to NEFOP allocations. Stock areas are Gulf of Maine (GOM), Georges Bank (GBK), southern New England/mid-Atlantic (SNE), northern (NOR), and southern (SOU). Note: allocations may not sum to 100 due to rounding.

Species	**Total Observer species landings (kg)**	**Total VTR species landings (kg)**	**Stock area**	**NEFOP landings allocation (kg)**	**VTR landings allocation (kg)**	**VMS landings allocation (kg)**	**NEFOP stock allocation (%)**	**VTR stock allocation (%)**	***VTR difference (%)***	**VMS stock allocation (%)**	***VMS difference (%)***
Atlantic cod (*Gadus morhua*)	134,732	121,281	GBK	121,143	110,140	109,975	89.9	90.8	-0.9	**90.7**	**-0.8**
			GOM	13,588	11,141	11,306	10.1	9.2	0.9	**9.3**	**0.8**
Haddock (*Melanogrammus aeglefinus*)	507,806	501,287	GBK	499,955	493,985	494,177	98.5	**98.5**	**-0.1**	98.6	-0.1
			GOM	7,851	7,302	7,110	1.5	**1.5**	**0.1**	1.4	0.1
Yellowtail flounder (*Limanda ferruginea*)	252,865	281,582	GBK	247,173	271,682	274,809	97.7	96.5	1.3	**97.6**	**0.2**
			GOM	5,582	9,900	6,684	2.2	3.5	-1.3	**2.4**	**-0.2**
			SNE	109		88	0.0	0.0	0.0	**0.0**	**0.0**
Winter flounder (*Pseudopleuronectes americanus*)	170,741	203,914	GBK	152,184	168,733	184,100	89.1	82.7	6.4	**90.3**	**-1.2**
			GOM	5,362	4,452	4,727	3.1	2.2	1.0	**2.3**	**0.8**
			SNE	13,194	30,729	15,087	7.7	15.1	-7.3	**7.4**	**0.3**
Windowpane flounder (*Scophthalmus aquosus*)	153	66	NOR	144	66	42	94.4	**100.0**	**-5.6**	64.3	30.0
			SOU	9	0	23	5.6	**0.0**	**5.6**	35.7	-30.0
Goosefish (*Lophius americanus*)	380,531	71,311	NOR	335,799	54,720	55,942	88.2	76.7	11.5	**78.4**	**9.8**
			SOU	44,732	16,591	15,369	11.8	23.3	-11.5	**21.6**	**-9.8**
Silver hake (*Merluccius bilnearis*)	24,840	23,280	NOR	4,614	3,685	5,031	18.6	**15.8**	**2.7**	21.6	-3.0
			SOU	20,226	19,595	18,250	81.4	**84.2**	**-2.7**	78.4	3.0
Red hake (*Urophycis chuss*)	2,869	2,655	NOR	1,252	797	850	43.6	30.0	13.6	**32.0**	**11.6**
			SOU	1,617	1,858	1,805	56.4	70.0	-13.6	**68.0**	**-11.6**

Table 7. Comparison of the Northeast Fisheries Observer Program (NEFOP), Vessel Trip Reports (VTR), and Vessel Monitoring System (VMS) stock allocations of 2005 commercial landings based on 901 matched trips. Bold text is used to indicate which method, VTR or VMS, achieve results closest to NEFOP allocations. Stock areas are Gulf of Maine (GOM), Georges Bank (GBK), southern New England/mid-Atlantic (SNE), northern (NOR), and southern (SOU). Note: allocations may not sum to 100 due to rounding.

Species	**Total Observer species landings (kg)**	**Total VTR species landings (kg)**	**Stock area**	**NEFOP landings allocation (kg)**	**VTR landings allocation (kg)**	**VMS landings allocation (kg)**	**NEFOP stock allocation (%)**	**VTR stock allocation (%)**	***VTR difference (%)***	**VMS stock allocation (%)**	***VMS difference (%)***
Atlantic cod *(Gadus morhua)*	653,066	593,995	GBK	599,457	545,989	541,523	91.8	**91.9**	**-0.1**	91.2	0.6
			GOM	53,609	48,006	52,472	8.2	**8.1**	**0.1**	8.8	-0.6
Haddock *(Melanogrammus aeglefinus)*	1,456,503	1,481,989	GBK	1,431,364	1,440,899	1,433,354	98.3	**97.2**	**1.0**	96.7	1.6
			GOM	25,139	41,090	48,635	1.7	**2.8**	**-1.0**	3.3	-1.6
Yellowtail flounder *(Limanda ferruginea)*	780,959	817,279	GBK	758,539	773,181	791,561	97.1	94.6	2.5	**96.9**	**0.3**
			GOM	21,652	23,010	24,687	2.8	2.8	0.0	**3.0**	**-0.2**
			SNE	768	21,088	1,030	0.1	2.6	-2.5	**0.1**	**0.0**
Winter flounder *(Pseudopleuronectes americanus)*	548,666	640,737	GBK	463,772	520,883	534,598	84.5	81.3	3.2	**83.4**	**1.1**
			GOM	9,403	26,073	8,308	1.7	4.1	-2.4	**1.3**	**0.4**
			SNE	75,491	93,781	97,831	13.8	14.6	-0.9	**15.3**	**-1.5**
Windowpane flounder *(Scophthalmus aquosus)*	16,477	13,851	NOR	16,460	13,398	13,780	99.9	96.7	3.2	**99.5**	**0.4**
			SOU	16	454	71	0.1	3.3	-3.2	**0.5**	**-0.4**
Goosefish *(Lophius americanus)*	1,277,812	268,890	NOR	898,895	166,563	172,457	70.3	61.9	8.4	**64.1**	**6.2**
			SOU	378,917	102,327	96,433	29.7	38.1	-8.4	**35.9**	**-6.2**
Silver hake *(Merluccius bilnearis)*	75,370	72,752	NOR	23,266	26,305	26,140	30.9	36.2	-5.3	**35.9**	**-5.1**
			SOU	52,104	46,447	46,612	69.1	63.8	5.3	**64.1**	**5.1**
Red hake *(Urophycis chuss)*	4,165	3,877	NOR	3,139	2,592	2,769	75.4	66.9	8.5	**71.4**	**3.9**
			SOU	1,025	1,285	1,107	24.6	33.1	-8.5	**28.6**	**-3.9**

Table 8. Comparison of the Northeast Fisheries Observer Program (NEFOP), Vessel Trip Reports (VTR), and Vessel Monitoring System (VMS) stock allocations of 2006 commercial landings based on 514 matched trips. Bold text is used to indicate which method, VTR or VMS, achieve results closest to NEFOP allocations. Stock areas are Gulf of Maine (GOM), Georges Bank (GBK), southern New England/mid-Atlantic (SNE), northern (NOR), and southern (SOU). Note: allocations may not sum to 100 due to rounding.

Species	Total Observer species landings (kg)	Total VTR species landings (kg)	Stock area	NEFOP landings allocation (kg)	VTR landings allocation (kg)	VMS landings allocation (kg)	NEFOP stock allocation (%)	VTR stock allocation (%)	*VTR difference (%)*	VMS stock allocation (%)	*VMS difference (%)*
Atlantic cod (*Gadus morhua*)	234,013	207,562	GBK	201,266	176,561	177,335	86.0	85.1	0.9	**85.4**	**0.6**
			GOM	32,747	31,001	30,227	14.0	14.9	-0.9	**14.6**	**-0.6**
Haddock (*Melanogrammus aeglefinus*)	312,195	286,961	GBK	304,139	268,746	275,605	97.4	93.7	3.8	**96.0**	**1.4**
			GOM	8,056	18,215	11,356	2.6	6.3	-3.8	**4.0**	**-1.4**
Yellowtail flounder (*Limanda ferruginea*)	270,492	288,175	GBK	256,683	277,142	275,958	94.9	96.2	-1.3	**95.8**	**-0.9**
			GOM	12,548	10,029	10,530	4.6	3.5	1.2	**3.7**	**1.0**
			SNE	1,261	1,004	1,686	0.5	0.3	0.1	**0.6**	**-0.1**
Winter flounder (*Pseudopleuronectes americanus*)	193,511	202,203	GBK	165,082	168,158	171,834	85.3	83.2	2.1	**85.0**	**0.3**
			GOM	3,109	2,827	2,834	1.6	1.4	0.2	**1.4**	**0.2**
			SNE	25,321	31,219	27,535	13.1	15.4	-2.4	**13.6**	**-0.5**
Windowpane flounder (*Scophthalmus aquosus*)	11,167	8,308	NOR	10,964	7,745	8,026	98.2	93.2	5.0	**96.6**	**1.6**
			SOU	204	563	282	1.8	6.8	-5.0	**3.4**	**-1.6**
Goosefish (*Lophius americanus*)	697,289	150,874	NOR	450,096	105,992	110,857	64.5	**70.3**	**-5.7**	73.5	-8.9
			SOU	247,193	44,883	40,017	35.5	**29.7**	**5.7**	26.5	8.9
Silver hake (*Merluccius bilnearis*)	67,997	57,500	NOR	30,157	23,221	23,584	44.4	40.4	4.0	**41.0**	**3.3**
			SOU	37,840	34,278	33,916	55.6	59.6	-4.0	**59.0**	**-3.3**
Red hake (*Urophycis chuss*)	5,318	4,354	NOR	3,888	2,908	3,328	73.1	66.8	6.3	**76.4**	**-3.3**
			SOU	1,431	1,447	1,027	26.9	33.2	-6.3	**23.6**	**3.3**

Table 9. Comparison of the Northeast Fisheries Observer Program (NEFOP), Vessel Trip Reports (VTR), and Vessel Monitoring System (VMS) stock allocations of 2007 commercial landings based on 771 matched trips. Bold text is used to indicate which method, VTR or VMS, achieve results closest to NEFOP allocations. Stock areas are Gulf of Maine (GOM), Georges Bank (GBK), southern New England/mid-Atlantic (SNE), northern (NOR), and southern (SOU). Note: allocations may not sum to 100 due to rounding.

Species	Total Observer species landings (kg)	Total VTR species landings (kg)	Stock area	NEFOP landings allocation (kg)	VTR landings allocation (kg)	VMS landings allocation (kg)	NEFOP stock allocation (%)	VTR stock allocation (%)	*VTR difference (%)*	VMS stock allocation (%)	*VMS difference (%)*
Atlantic cod			GBK	406,039	389,822	383,746	88.5	**88.8**	**-0.2**	87.4	1.1
(Gadus morhua)	458,590	439,098	GOM	52,552	49,276	55,352	11.5	**11.2**	**0.2**	12.6	-1.1
Haddock			GBK	420,707	427,180	423,005	96.7	**95.9**	**0.8**	95.0	1.7
(Melanogrammus aeglefinus)	434,982	445,240	GOM	14,275	18,060	22,235	3.3	**4.1**	**-0.8**	5.0	-1.7
Yellowtail flounder			GBK	177,581	189,671	191,276	89.1	**89.4**	**-0.3**	90.1	-1.0
(Limanda ferruginea)			GOM	17,868	19,131	17,445	9.0	**9.0**	**0.0**	8.2	0.7
	199,270	212,210	SNE	3,821	3,408	3,489	1.9	**1.6**	**0.3**	1.6	0.3
Winter flounder			GBK	153,281	170,371	161,318	72.7	**69.1**	**3.7**	65.4	7.3
(Pseudopleuronectes americanus)			GOM	5,526	5,257	8,429	2.6	**2.1**	**0.5**	3.4	-0.8
	210,757	246,681	SNE	51,951	71,053	76,934	24.6	**28.8**	**-4.2**	31.2	-6.5
Windowpane flounder			NOR	13,637	10,286	10,329	94.5	93.7	0.8	**94.1**	**0.4**
(Scophthalmus aquosus)	14,428	10,979	SOU	792	693	650	5.5	6.3	-0.8	**5.9**	**-0.4**
Goosefish			NOR	327,731	69,999	70,227	70.4	70.1	0.3	**70.3**	**0.1**
(Lophius americanus)	465,492	99,856	SOU	137,761	29,857	29,629	29.6	29.9	-0.3	**29.7**	**-0.1**
Silver hake			NOR	26,292	37,105	34,143	35.5	37.1	-1.6	**34.1**	**1.4**
(Merluccius bilnearis)	74,105	100,047	SOU	47,813	62,942	65,905	64.5	62.9	1.6	**65.9**	**-1.4**
Red hake			NOR	8,698	7,163	7,051	63.0	**51.0**	**12.1**	50.2	12.9
(Urophycis chuss)	13,803	14,055	SOU	5,105	6,892	7,005	37.0	**49.0**	**-12.1**	49.8	-12.9

Table 10. Comparison of the Northeast Fisheries Observer Program (NEFOP), Vessel Trip Reports (VTR), and Vessel Monitoring System (VMS) stock allocations of 2008 commercial landings based on 655 matched trips. Bold text is used to indicate which method, VTR or VMS, achieve results closest to NEFOP allocations. Stock areas are Gulf of Maine (GOM), Georges Bank (GBK), southern New England/mid-Atlantic (SNE), northern (NOR), and southern (SOU). Note: allocations may not sum to 100 due to rounding.

Species	Total Observer species landings (kg)	Total VTR species landings (kg)	Stock area	NEFOP landings allocation (kg)	VTR landings allocation (kg)	VMS landings allocation (kg)	NEFOP stock allocation (%)	VTR stock allocation (%)	*VTR difference (%)*	VMS stock allocation (%)	*VMS difference (%)*
Atlantic cod			GBK	351,095	315,830	311,392	87.5	88.3	-0.8	**87.1**	**0.4**
(Gadus morhua)	401,344	357,702	GOM	50,249	41,872	46,310	12.5	11.7	0.8	**12.9**	**-0.4**
Haddock			GBK	743,721	725,050	719,921	98.8	**98.3**	**0.5**	97.6	1.2
(Melanogrammus aeglefinus)	752,855	737,893	GOM	9,134	12,843	17,971	1.2	**1.7**	**-0.5**	2.4	-1.2
Yellowtail flounder			GBK	197,165	218,113	215,660	93.1	93.9	-0.9	**92.9**	**0.2**
(Limanda ferruginea)			GOM	12,527	11,436	12,813	5.9	4.9	1.0	**5.5**	**0.4**
	211,839	232,198	SNE	2,147	2,649	3,725	1.0	**1.1**	**-0.1**	1.6	-0.6
Winter flounder			GBK	229,437	273,771	256,775	84.6	**84.0**	**0.6**	78.8	5.8
(Pseudopleuronectes americanus)			GOM	7,419	5,975	8,527	2.7	**1.8**	**0.9**	2.6	0.1
	271,056	325,728	SNE	34,201	45,982	60,426	12.6	**14.1**	**-1.5**	18.6	-5.9
Windowpane flounder			NOR	7,265	7,096	6,942	88.7	**86.9**	**1.8**	85.0	3.7
(Scophthalmus aquosus)	8,190	8,169	SOU	926	1072	1226	11.3	**13.1**	**-1.8**	15.0	-3.7
Goosefish			NOR	180,968	32,766	35,171	53.5	51.5	2.0	**55.3**	**-1.8**
(Lophius americanus)	338,356	63,624	SOU	157,388	30,857	28,453	46.5	48.5	-2.0	**44.7**	**1.8**
Silver hake			NOR	9,805	13,200	13,130	21.2	27.3	-6.0	**27.1**	**-5.9**
(Merluccius bilnearis)	46,151	48,412	SOU	36,346	35,212	35,282	78.8	72.7	6.0	**72.9**	**5.9**
Red hake			NOR	11,410	7,531	7,536	76.8	68.0	8.7	**68.1**	**8.7**
(Urophycis chuss)	14,864	11,068	SOU	3,454	3,538	3,532	23.2	32.0	-8.7	**31.9**	**-8.7**

Table 11. Species-level summary of the Vessel Monitoring System (VMS) dataset and Vessel Trip Reports (VTR) subset compared to total VTR landings (kg) from 2004 to 2008.

Year	Species	Total VTR landings (kg)	VTR subset (kg)	Percent of total (%)	VMS matched set (kg)	Percent of total (%)
2004	Atlantic cod *(Gadus morhua)*	5,611,244	5,432,809	96.8	1,874,015	33.4
	Haddock *(Melanogrammus aeglefinus)*	6,919,871	6,837,521	98.8	5,096,088	73.6
	Yellowtail flounder *(Limanda ferruginea)*	6,954,627	6,899,760	99.2	5,378,986	77.3
	Winter flounder *(Pseudopleuronectes americanus)*	4,515,996	4,483,488	99.3	3,127,780	69.3
	Windowpane flounder *(Scophthalmus aquosus)*	92,640	91,522	98.8	18,217	19.7
	Goosefish *(Lophius americanus)*	7,561,854	7,440,979	98.4	1,332,178	17.6
	Silver hake *(Merluccius bilinearis)*	7,454,395	7,392,633	99.2	2,071,931	27.8
	Red hake *(Urophycis chuss)*	875,228	863,357	98.6	236,830	27.1
2005	Atlantic cod *(Gadus morhua)*	5,072,510	4,983,113	98.2	2,754,687	54.3
	Haddock *(Melanogrammus aeglefinus)*	6,198,222	6,155,937	99.3	5,700,737	92.0
	Yellowtail flounder *(Limanda ferruginea)*	3,925,078	3,922,078	99.9	3,475,993	88.6
	Winter flounder *(Pseudopleuronectes americanus)*	3,473,132	3,457,729	99.6	2,800,639	80.6
	Windowpane flounder *(Scophthalmus aquosus)*	81,693	81,532	99.8	45,771	56.0
	Goosefish *(Lophius americanus)*	7,377,131	7,259,875	98.4	2,129,989	28.9
	Silver hake *(Merluccius bilinearis)*	7,526,280	7,522,877	100.0	3,531,069	46.9
	Red hake *(Urophycis chuss)*	549,641	547,200	99.6	154,666	28.1
2006	Atlantic cod *(Gadus morhua)*	4,623,801	4,546,055	98.3	3,428,790	74.2
	Haddock *(Melanogrammus aeglefinus)*	2,810,657	2,713,290	96.5	2,513,767	89.4
	Yellowtail flounder *(Limanda ferruginea)*	1,891,367	1,867,650	98.7	1,681,115	88.9
	Winter flounder *(Pseudopleuronectes americanus)*	2,589,643	2,583,503	99.8	2,128,052	82.2
	Windowpane flounder *(Scophthalmus aquosus)*	87,187	87,012	99.8	61,654	70.7
	Goosefish *(Lophius americanus)*	6,109,614	6,026,365	98.6	3,246,832	53.1
	Silver hake *(Merluccius bilinearis)*	5,331,664	5,327,921	99.9	4,606,490	86.4
	Red hake *(Urophycis chuss)*	559,679	553,489	98.9	458,731	82.0
2007	Atlantic cod *(Gadus morhua)*	6,278,969	6,171,416	98.3	5,838,287	93.0
	Haddock *(Melanogrammus aeglefinus)*	3,071,154	3,054,852	99.5	3,013,511	98.1
	Yellowtail flounder *(Limanda ferruginea)*	1,675,883	1,668,462	99.6	1,623,035	96.8
	Winter flounder *(Pseudopleuronectes americanus)*	2,517,944	2,499,538	99.3	2,172,096	86.3
	Windowpane flounder *(Scophthalmus aquosus)*	180,091	179,389	99.6	144,231	80.1
	Goosefish *(Lophius americanus)*	4,797,261	4,677,828	97.5	2,969,033	61.9
	Silver hake *(Merluccius bilinearis)*	6,198,030	6,179,560	99.7	5,749,198	92.8
	Red hake *(Urophycis chuss)*	614,724	606,624	98.7	544,902	88.6
2008	Atlantic cod *(Gadus morhua)*	7,026,980	6,942,829	98.8	4,987,617	71.0
	Haddock *(Melanogrammus aeglefinus)*	5,213,529	5,190,698	99.6	4,072,033	78.1
	Yellowtail flounder *(Limanda ferruginea)*	1,624,491	1,616,847	99.5	1,239,577	76.3
	Winter flounder *(Pseudopleuronectes americanus)*	2,226,518	2,210,008	99.3	1,875,233	84.2
	Windowpane flounder *(Scophthalmus aquosus)*	117,138	116,527	99.5	59,340	50.7
	Goosefish *(Lophius americanus)*	4,189,612	4,046,358	96.6	1,791,932	42.8
	Silver hake *(Merluccius bilinearis)*	5,767,216	5,583,469	96.8	3,801,904	65.9
	Red hake *(Urophycis chuss)*	754,050	716,744	95.1	535,823	71.1

Table 12. 2004 summary of the Vessel Monitoring System (VMS) data subsets compared to the subset of Vessel Trip Reports (VTR) landings (kg), by species and gear type (bottom otter trawl gear = OTF, scallop dredge gear = DRS, sink gillnet = GNS, and benthic longline = LLB).

Species	VTR gear code	VTR Number of Vessels	VTR Number of trips	VTR landings (kg)	VMS Number of Vessels	VMS Number of trips	VMS landings (kg)	Percent of VTR landings (%)
Atlantic cod *(Gadus morhua)*	OTF	444	9,167	3,507,919	189	2,724	1,829,688	52.2
	DRS	6	9	535	3	3	14	2.5
	GNS	171	6,972	1,726,238	4	116	25,959	1.5
	LLB	67	1,221	198,117	21	253	18,355	9.3
Haddock *(Melanogrammus aeglefinus)*	OTF	384	6,323	5,908,548	187	2,472	4,619,014	78.2
	DRS	1	1	0	0	0	0	*N/A*
	GNS	137	3,313	133,401	3	86	9,789	7.3
	LLB	55	986	795,572	21	261	467,285	58.7
Yellowtail flounder *(Limanda ferruginea)*	OTF	404	7,337	6,749,688	181	2,061	5,373,053	79.6
	DRS	36	62	4,346	33	48	4,072	93.7
	GNS	93	1,541	145,727	2	31	1,862	1.3
	LLB	0	0	0	0	0	0	*N/A*
Winter flounder *(Pseudopleuronectes americanus)*	OTF	471	9,866	4,393,835	184	2,314	3,125,651	71.1
	DRS	18	37	750	16	26	660	87.9
	GNS	129	3,029	88,606	2	57	1,433	1.6
	LLB	9	67	298	2	10	37	12.3
Windowpane flounder *(Scophthalmus aquosus)*	OTF	158	1,291	90,880	46	105	18,217	20.0
	DRS	0	0	0	0	0	0	*N/A*
	GNS	12	63	642	0	0	0	0.0
	LLB	0	0	0	0	0	0	*N/A*
Goosefish *(Lophius americanus)*	OTF	555	9,467	1,870,948	208	2,325	880,759	47.1
	DRS	226	1,226	381,761	214	1,179	380,203	99.6
	GNS	268	8,119	5,186,982	4	118	70,362	1.4
	LLB	26	146	1,288	16	75	854	66.3
Silver hake *(Merluccius bilinearis)*	OTF	234	3,212	7,334,373	68	721	2,069,807	28.2
	DRS	0	0	0	0	0	0	*N/A*
	GNS	63	415	21,948	2	7	1,976	9.0
	LLB	4	17	36,311	2	4	148	0.4
Red hake *(Urophycis chuss)*	OTF	172	2,226	769,215	56	510	235,494	30.6
	DRS	0	0	0	0	0	0	*N/A*
	GNS	26	353	93,767	1	33	1,044	1.1
	LLB	7	21	376	3	7	292	77.6

Table 13. 2005 summary of the Vessel Monitoring System (VMS) data subsets compared to the subset of Vessel Trip Reports (VTR) landings (kg), by species and gear type (bottom otter trawl gear = OTF, scallop dredge gear = DRS, sink gillnet = GNS, and benthic longline = LLB).

		VTR			VMS			
Species	**VTR gear code**	**Number of Vessels**	**Number of trips**	**VTR landings (kg)**	**Number of Vessels**	**Number of trips**	**VMS landings (kg)**	**Percent of VTR landings (%)**
Atlantic cod *(Gadus morhua)*	OTF	381	9,005	3,201,456	229	4,415	2,491,742	77.8
	DRS	8	11	1,209	7	10	100	8.3
	GNS	157	6,711	1,574,496	21	697	164,299	10.4
	LLB	89	1,373	205,952	45	638	98,546	47.8
Haddock *(Melanogrammus aeglefinus)*	OTF	342	6,471	5,246,396	217	3,670	5,036,560	96
	DRS	3	4	15	2	3	14	93.9
	GNS	125	3,054	59,757	15	292	4,494	7.5
	LLB	80	1257	849,769	44	650	659,669	77.6
Yellowtail flounder *(Limanda ferruginea)*	OTF	352	7,138	3,815,235	218	3,175	3,473,828	91.1
	DRS	30	45	2,059	28	42	1,883	91.5
	GNS	77	1,180	104,756	5	30	259	0.2
	LLB	5	19	28	3	16	23	83.6
Winter flounder *(Pseudopleuronectes americanus)*	OTF	413	9,225	3,407,204	229	3,458	2,786,325	81.8
	DRS	37	65	13,237	36	64	12,772	96.5
	GNS	118	2,530	36,739	12	189	1,069	2.9
	LLB	11	84	549	6	66	473	86.1
Windowpane flounder *(Scophthalmus aquosus)*	OTF	158	1,057	80,999	78	227	45,762	56.5
	DRS	0	0	0	0	0	0	*N/A*
	GNS	9	77	523	0	0	0	0.0
	LLB	4	9	10	3	8	9	91.3
Goosefish *(Lophius americanus)*	OTF	493	9,197	1,857,280	260	3,603	1,359,021	73.2
	DRS	317	2,722	335,072	266	1,498	321,271	95.9
	GNS	246	8,736	5,065,683	34	801	448,437	8.9
	LLB	36	212	1,841	30	182	1,260	68.4
Silver hake *(Merluccius bilinearis)*	OTF	193	2,689	7,391,321	96	1197	3,489,085	47.2
	DRS	2	2	365	2	2	365	100.0
	GNS	41	255	20,219	1	8	4,400	21.8
	LLB	7	30	110,972	5	20	37,219	33.5
Red hake *(Urophycis chuss)*	OTF	143	1,838	482,879	69	757	152,655	31.6
	DRS	1	1	125	1	1	125	100.0
	GNS	24	239	64,020	2	25	1,810	2.8
	LLB	4	10	176	2	6	76	43.3

Table 14. 2006 summary of the Vessel Monitoring System (VMS) data subsets compared to the subset of Vessel Trip Reports (VTR) landings (kg), by species and gear type (bottom otter trawl gear = OTF, scallop dredge gear = DRS, sink gillnet = GNS, and benthic longline = LLB).

Species	VTR gear code	VTR			VMS			
		Number of Vessels	Number of trips	VTR landings (kg)	Number of Vessels	Number of trips	VMS landings (kg)	Percent of VTR landings (%)
Atlantic cod *(Gadus morhua)*	OTF	350	7,493	2,913,548	301	5,799	2,680,732	92.0
	DRS	5	8	420	4	7	184	43.8
	GNS	153	6,764	1,427,295	95	2739	656,843	46.0
	LLB	80	1,154	204,792	42	511	91,031	44.5
Haddock *(Melanogrammus aeglefinus)*	OTF	296	4,938	2,242,491	252	3,994	2,186,209	97.5
	DRS	5	5	1,303	4	4	1,299	99.7
	GNS	122	2,964	65,539	75	1275	26,864	41.0
	LLB	76	1091	403,958	42	496	299,395	74.1
Yellowtail flounder *(Limanda ferruginea)*	OTF	319	6,402	1,772,976	282	4,938	1,674,672	94.5
	DRS	24	36	4,098	23	35	4,076	99.4
	GNS	67	1,293	90,562	32	244	2,355	2.6
	LLB	5	12	14	4	11	13	96.7
Winter flounder *(Pseudopleuronectes americanus)*	OTF	381	8,460	2,534,691	310	5,530	2,115,716	83.5
	DRS	36	73	4,951	34	71	4,926	99.5
	GNS	109	2,825	43,398	64	979	6,983	16.1
	LLB	8	57	463	7	42	428	92.5
Windowpane flounder *(Scophthalmus aquosus)*	OTF	151	1,246	86,897	117	607	61,621	70.9
	DRS	1	2	7	1	2	7	100.0
	GNS	9	37	107	3	7	24	22.6
	LLB	1	1	2	1	1	2	100.0
Goosefish *(Lophius americanus)*	OTF	459	8,032	1,574,844	380	5,747	1,417,361	90.0
	DRS	336	3,917	323,214	333	3,650	317,777	98.3
	GNS	261	8,050	4,127,303	114	2910	1,510,988	36.6
	LLB	22	113	1,004	20	99	706	70.3
Silver hake *(Merluccius bilinearis)*	OTF	197	3,098	5,294,681	162	2242	4,590,130	86.7
	DRS	1	3	14	1	3	14	100.0
	GNS	37	251	18,600	22	98	11,729	63.1
	LLB	4	13	14,628	3	5	4,616	31.6
Red hake *(Urophycis chuss)*	OTF	152	1,983	525,546	119	1346	447,917	85.2
	DRS	2	2	29	2	2	29	100.0
	GNS	22	257	27,383	10	112	10,260	37.5
	LLB	4	6	531	3	5	524	98.7

Table 15. 2007 summary of the Vessel Monitoring System (VMS) data subsets compared to the subset of Vessel Trip Reports (VTR) landings (kg), by species and gear type (bottom otter trawl gear = OTF, scallop dredge gear = DRS, sink gillnet = GNS, and benthic longline = LLB).

Species	VTR gear code	VTR Number of Vessels	VTR Number of trips	VTR landings (kg)	VMS Number of Vessels	VMS Number of trips	VMS landings (kg)	Percent of VTR landings (%)
Atlantic cod	OTF	333	7,166	3,722,919	322	6,538	3,592,723	96.5
(Gadus morhua)	DRS	6	11	122	6	11	122	100.0
	GNS	145	7,724	2,224,006	135	7059	2,038,677	91.7
	LLB	62	1,048	224,369	54	952	206,764	92.2
Haddock	OTF	273	4,508	2,623,998	270	4,220	2,603,164	99.2
(Melanogrammus aeglefinus)	DRS	3	5	29	3	5	29	100.0
	GNS	113	2,985	60,006	113	2851	58,541	97.6
	LLB	60	1007	370,818	55	946	351,777	94.9
Yellowtail flounder	OTF	306	6,360	1,592,293	298	5,718	1,558,752	97.9
(Limanda ferruginea)	DRS	21	34	991	21	34	991	100.0
	GNS	78	2,089	73,751	76	1872	63,226	85.7
	LLB	6	8	1,427	5	7	66	4.6
Winter flounder	OTF	360	8,748	2,442,367	327	6,449	2,120,496	86.8
(Pseudopleuronectes americanus)	DRS	37	76	6,369	37	76	6,369	100.0
	GNS	124	3,877	50,230	104	3474	44,687	89.0
	LLB	6	45	572	5	43	545	95.3
Windowpane flounder	OTF	182	1,865	179,240	159	1133	144,127	80.4
(Scophthalmus aquosus)	DRS	1	1	5	1	1	5	100.0
	GNS	7	51	144	4	46	99	68.9
	LLB	0	0	0	0	0	0	*N/A*
Goosefish	OTF	412	6,928	811,850	367	5,586	782,931	96.4
(Lophius americanus)	DRS	330	3,458	421,485	323	3,223	417,292	99.0
	GNS	249	7,546	3,444,297	169	5152	1,768,626	51.3
	LLB	16	53	195	16	51	184	94.2
Silver hake	OTF	201	3,830	6,112,602	180	3023	5,685,483	93.0
(Merluccius bilinearis)	DRS	3	3	8	3	3	8	100.0
	GNS	50	562	24,962	45	538	23,987	96.1
	LLB	5	32	41,988	5	31	39,720	94.6
Red hake	OTF	157	2,637	590,951	130	2043	531,345	89.9
(Urophycis chuss)	DRS	0	0	0	0	0	0	*N/A*
	GNS	18	247	15,673	14	235	13,557	86.5
	LLB	0	0	0	0	0	0	*N/A*

Table 16. 2008 summary of the Vessel Monitoring System (VMS) data subsets compared to the subset of Vessel Trip Reports (VTR) landings (kg), by species and gear type (bottom otter trawl gear = OTF, scallop dredge gear = DRS, sink gillnet = GNS, and benthic longline = LLB).

Species	VTR gear code	VTR Number of Vessels	VTR Number of trips	VTR landings (kg)	VMS Number of Vessels	VMS Number of trips	VMS landings (kg)	Percent of VTR landings (%)
Atlantic cod	OTF	319	8,051	3,980,275	283	5,545	2,782,826	69.9
(Gadus morhua)	DRS	3	3	20	1	1	9	45.5
	GNS	145	9,193	2,776,208	130	6811	2,052,888	73.9
	LLB	59	871	186,327	47	652	151,893	81.5
Haddock	OTF	250	4,469	4,740,122	230	3,129	3,667,918	77.4
(Melanogrammus aeglefinus)	DRS	1	2	41	1	2	41	100.0
	GNS	111	3,128	55,863	106	2402	42,170	75.5
	LLB	56	657	394,672	46	540	361,904	91.7
Yellowtail flounder	OTF	290	6,869	1,499,440	257	4,825	1,163,165	77.6
(Limanda ferruginea)	DRS	14	35	1,301	14	34	1,251	96.2
	GNS	90	2,725	111,067	84	1773	74,741	67.3
	LLB	6	59	5,039	4	9	420	8.3
Winter flounder	OTF	346	8,642	2,150,549	294	5,328	1,832,963	85.2
(Pseudopleuronectes americanus)	DRS	24	41	2,139	19	30	1,424	66.6
	GNS	125	4,402	56,329	100	3149	40,113	71.2
	LLB	8	102	992	6	49	733	73.9
Windowpane flounder	OTF	167	1,863	115,475	127	796	58,557	50.7
(Scophthalmus aquosus)	DRS	1	1	1	0	0	0	0.0
	GNS	19	80	1,051	8	33	782	74.4
	LLB	0	0	0	0	0	0	*N/A*
Goosefish	OTF	378	5,872	614,655	300	3,595	405,446	66.0
(Lophius americanus)	DRS	323	2,800	304,618	290	1,971	233,700	76.7
	GNS	237	6,226	3,126,971	147	3362	1,152,723	36.9
	LLB	7	24	114	4	15	62	54.4
Silver hake	OTF	205	3,518	5,541,597	164	2186	3,767,703	68.0
(Merluccius bilinearis)	DRS	0	0	0	0	0	0	*N/A*
	GNS	62	804	41,852	54	690	34,181	81.7
	LLB	3	4	20	3	4	20	100.0
Red hake	OTF	161	2,558	708,281	124	1532	527,891	74.5
(Urophycis chuss)	DRS	1	1	16	0	0	0	0.0
	GNS	19	298	8,284	14	257	7,783	94.0
	LLB	3	5	163	2	4	149	91.6

Table 17. Summary of the agreement levels between statistical areas recorded on Vessel Trip Reports (VTR) and the statistical areas fished as determined using Vessel Monitoring System (VMS) positional data from matched fishing trips from 2004 to 2008. Trip subcategories are based on the VMS determined number of statistical areas fished. Note: percentages may not sum to 100 due to rounding.

Year	Trip category	Number of trips	Agreement level	Number of trips	Percent of total category trips (%)
2004	Single area	2,895	Complete	2,688	92.8
			None	194	6.7
			Partial	13	0.4
	Multi-area	2,997	Complete	74	2.5
			None	139	4.6
			Partial	2,784	92.9
2005	Single area	5,630	Complete	5,267	93.6
			None	334	5.9
			Partial	29	0.5
	Multi-area	4,279	Complete	265	6.2
			None	206	4.8
			Partial	3,808	89.0
2006	Single area	13,488	Complete	12,869	95.4
			None	590	4.4
			Partial	29	0.2
	Multi-area	5,677	Complete	234	4.1
			None	221	3.9
			Partial	5,222	92.0
2007	Single area	19,917	Complete	19,104	95.9
			None	785	3.9
			Partial	28	0.1
	Multi-area	6,007	Complete	284	4.7
			None	234	3.9
			Partial	5,489	91.4
2008	Single area	16,797	Complete	16,124	96.0
			None	641	3.8
			Partial	32	0.2
	Multi-area	4,028	Complete	172	4.3
			None	170	4.2
			Partial	3,686	91.5

Table 18. Frequency of trips fishing on multiple stocks based on Vessel Monitoring System (VMS) data from 2004 to 2008.

Species	2004			2005			2006			2007			2008		
	Total trips	Multiple stock area trips	Percent (%)	Total trips	Multiple stock area trips	Percent (%)	Total trips	Multiple stock area trips	Percent (%)	Total trips	Multiple stock area trips	Percent (%)	Total trips	Multiple stock area trips	Percent (%)
Atlantic cod *(Gadus morhua)*	3,096	304	9.8	5,760	600	10.4	9,056	555	6.1	14,560	539	3.7	13,009	340	2.6
Haddock *(Melanogrammus aeglefinus)*	2,819	295	10.5	4,615	562	12.2	5,769	517	9	8,022	464	5.8	6,073	306	5.0
Yellowtail flounder *(Limanda ferruginea)*	2,140	186	8.7	3,263	352	10.8	5,228	367	7	7,631	436	5.7	6,641	264	4.0
Winter flounder *(Pseudopleuronectes americanus)*	2,407	286	11.9	3,777	604	16	6,622	453	6.8	10,042	490	4.9	8,556	327	3.8
Windowpane flounder *(Scophthalmus aquosus)*	105	19	18.1	236	24	10.2	617	28	4.5	1180	47	4.0	829	44	5.3
Goosefish *(Lophius americanus)*	3,697	254	6.9	6,084	511	8.4	12,406	580	4.7	14,012	426	3.0	8,943	300	3.4
Silver hake *(Merluccius bilinearis)*	732	17	2.3	1,227	28	2.3	2,348	38	1.6	3,595	59	1.6	2,880	28	1.0
Red hake *(Urophycis chuss)*	550	9	1.6	789	8	1	1,465	23	1.6	2,278	40	1.8	1,793	19	1.1

Table 19. Frequency of fixed (sink gillnet, benthic longline) and mobile (bottom otter trawl, scallop dredge) gear types used on trips fishing on multiple stocks based on Vessel Monitoring System (VMS) positional data from 2005.

Species	Number of total trips	Number of multiple stock area trips	Percent of total trips (%)	Gear category	Number of Trips	Percent of multiple stock area trips (%)
Atlantic cod *(Gadus morhua)*	5,760	600	10.4	Fixed	6	1.0
				Mobile	594	99.0
Haddock *(Melanogrammus aeglefinus)*	4,615	562	12.2	Fixed	4	0.7
				Mobile	558	99.3
Yellowtail flounder *(Limanda ferruginea)*	3,263	352	10.8	Fixed	0	0.0
				Mobile	352	100.0
Winter flounder *(Pseudopleuronectes americanus)*	3,777	604	16.0	Fixed	1	0.2
				Mobile	603	99.8
Windowpane flounder *(Scophthalmus aquosus)*	236	24	10.2	Fixed	0	0.0
				Mobile	24	100.0
Goosefish *(Lophius americanus)*	6,084	511	8.4	Fixed	0	0.0
				Mobile	511	100.0
Silver hake *(Merluccius bilinearis)*	1,227	28	2.3	Fixed	0	0.0
				Mobile	28	100.0
Red hake *(Urophycis chuss)*	789	8	1.0	Fixed	0	0.0
				Mobile	8	100.0

Table 20. Results of the Vessel Monitoring System (VMS) based stock area allocation compared to the stock area allocation based on the Vessel Trip Reports (VTR) reported statistical area for 2004. Relative difference is determined as % difference/VTR stock allocation; allocations ≥ 5.0% relative differences are italicized. Stock areas are Gulf of Maine (GOM), Georges Bank (GBK), southern New England/mid-Atlantic (SNE), northern (NOR), and southern (SOU). Note: allocations may not sum to 100 due to rounding.

Species	Total species landings (kg)	Stock area	VTR landings allocation (kg)	VMS landings allocation (kg)	Δ landings allocation abs(kg)	$\sum\Delta_i$/total species landings (%)	VTR stock allocation (%)	VMS Stock allocation (%)	Difference (%)	Relative difference (%)
Atlantic cod (*Gadus morhua*)	1,874,015	GBK	1,384,752	1,375,601	9,151	0.98	73.9	73.4	0.5	0.7
		GOM	489,263	498,414	9,151		26.1	26.6	-0.5	-1.9
Haddock (*Melanogrammus aeglefinus*)	5,096,088	GBK	4,763,038	4,806,095	43,057	1.69	93.5	94.3	-0.8	-0.9
		GOM	333,050	289,993	43,057		6.5	5.7	0.8	*12.3*
Yellowtail flounder (*Limanda ferruginea*)	5,378,987	GBK	5,094,590	5,176,798	82,208	3.06	94.7	96.2	-1.5	-1.6
		GOM	215,710	172,386	43,324		4.0	3.2	0.8	*20.0*
		SNE	68,687	29,802	38,885		1.3	0.6	0.7	*53.8*
Winter flounder (*Pseudopleuronectes americanus*)	3,127,781	GBK	2,420,182	2,459,208	39,026	2.59	77.4	78.6	-1.2	-1.6
		GOM	94,235	95,648	1,413		3.0	3.1	0.0	0.0
		SNE	613,364	572,925	40,439		19.6	18.3	1.3	*6.6*
Windowpane flounder (*Scophthalmus aquosus*)	18,217	NOR	16,807	16,725	82	0.90	92.3	91.8	0.5	0.5
		SOU	1,410	1,492	82		7.7	8.2	-0.5	*-6.5*
Goosefish (*Lophius americanus*)	1,332,178	NOR	787,572	801,448	13,876	2.08	59.1	60.2	-1.0	-1.7
		SOU	544,606	530,730	13,876		40.9	39.8	1.0	2.4
Silver hake (*Merluccius bilinearis*)	2,071,930	NOR	404,972	343,720	61,252	*5.91*	19.5	16.6	3.0	*15.4*
		SOU	1,666,958	1,728,210	61,252		80.5	83.4	-3.0	-3.7
Red hake (*Urophycis chuss*)	236,830	NOR	61,461	64,355	2,894	2.44	26.0	27.2	-1.2	-4.6
		SOU	175,369	172,475	2,894		74.0	72.8	1.2	1.6

Table 21. Results of the Vessel Monitoring System (VMS) based stock area allocation compared to the stock area allocation based on the Vessel Trip Reports (VTR) reported statistical area for 2005. Relative difference is determined as % difference/VTR stock allocation; allocations ≥ 5.0% relative differences are italicized. Stock areas are Gulf of Maine (GOM), Georges Bank (GBK), southern New England/mid-Atlantic (SNE), northern (NOR), and southern (SOU). Note: allocations may not sum to 100 due to rounding.

Species	**Total species landings (kg)**	**Stock area**	**VTR landings allocation (kg)**	**VMS landings allocation (kg)**	**Δ landings allocation abs(kg)**	**$\sum \Delta_i$/total species landings (%)**	**VTR stock allocation (%)**	**VMS stock allocation (%)**	**Difference (%)**	**Relative difference (%)**
Atlantic cod (*Gadus morhua*)	2,754,687	GBK	1,920,110	1,879,800	40,310	2.93	69.7	68.2	1.5	2.2
		GOM	834,577	874,887	40,310		30.3	31.8	-1.5	*-5.0*
Haddock (*Melanogrammus aeglefinus*)	5,700,737	GBK	5,319,329	5,285,374	33,955	1.19	93.3	92.7	0.6	0.6
		GOM	381,408	415,363	33,955		6.7	7.3	-0.6	*-9.0*
Yellowtail flounder (*Limanda ferruginea*)	3,475,993	GBK	3,115,140	3,164,191	49,051	2.82	89.6	91.0	-1.4	-1.6
		GOM	286,276	281,958	4,318		8.2	8.1	0.1	1.2
		SNE	74,577	29,844	44,733		2.1	0.9	1.3	*61.9*
Winter flounder (*Pseudopleuronectes americanus*)	2,800,638	GBK	1,976,251	1,985,963	9,712	1.39	70.6	70.9	-0.3	-0.4
		GOM	132,155	112,737	19,418		4.7	4.0	0.7	*14.9*
		SNE	692,232	701,939	9,707		24.7	25.1	-0.3	-1.2
Windowpane flounder (*Scophthalmus aquosus*)	45,772	NOR	43,740	44,337	597	2.61	95.6	96.9	-1.3	-1.4
		SOU	2,032	1,435	597		4.4	3.1	1.3	*29.5*
Goosefish (*Lophius americanus*)	2,129,989	NOR	1,188,433	1,223,924	35,491	3.33	55.8	57.5	-1.7	-3.0
		SOU	941,556	906,065	35,491		44.2	42.5	1.7	3.8
Silver hake (*Merluccius bilinearis*)	3,531,070	NOR	400,744	380,084	20,660	1.17	11.3	10.8	0.6	*5.3*
		SOU	3,130,326	3,150,986	20,660		88.7	89.2	-0.6	-0.7
Red hake (*Urophycis chuss*)	154,666	NOR	39,360	37,097	2,263	2.93	25.4	24.0	1.5	*5.9*
		SOU	115,306	117,569	2,263		74.6	76.0	-1.5	-2.0

Table 22. Results of the Vessel Monitoring System (VMS) based stock area allocation compared to the stock area allocation based on the Vessel Trip Reports (VTR) reported statistical area for 2006. Relative difference is determined as % difference/VTR stock allocation; allocations ≥ 5.0% relative differences are italicized. Stock areas are Gulf of Maine (GOM), Georges Bank (GBK), southern New England/mid-Atlantic (SNE), northern (NOR), and southern (SOU). Note: allocations may not sum to 100 due to rounding.

Species	Total species landings (kg)	Stock area	VTR landings allocation (kg)	VMS landings allocation (kg)	Δ landings allocation abs(kg)	$\sum\Delta_i$/total species landings (%)	VTR stock allocation (%)	VMS Stock allocation (%)	Difference (%)	Relative difference (%)
Atlantic cod (*Gadus morhua*)	3,428,790	GBK	2,012,366	2,009,838	2,528	0.15	58.7	58.6	0.1	0.2
		GOM	1,416,424	1,418,952	2,528		41.3	41.4	-0.1	-0.2
Haddock (*Melanogrammus aeglefinus*)	2,513,766	GBK	2,175,084	2,171,158	3,926	0.31	86.5	86.4	0.2	0.2
		GOM	338,682	342,608	3,926		13.5	13.6	-0.2	-1.5
Yellowtail flounder (*Limanda ferruginea*)	1,681,115	GBK	1,253,693	1,283,732	30,039	3.57	74.6	76.4	-1.8	-2.4
		GOM	319,177	315,714	3,463		19.0	18.8	0.2	1.1
		SNE	108,245	81,669	26,576		6.4	4.9	1.6	*25.0*
Winter flounder (*Pseudopleuronectes americanus*)	2,128,053	GBK	837,904	847,487	9,583	0.91	39.4	39.8	-0.5	-1.3
		GOM	151,351	151,497	146		7.1	7.1	0.0	0.0
		SNE	1,138,798	1,129,069	9,729		53.5	53.1	0.5	0.9
Windowpane flounder (*Scophthalmus aquosus*)	61,653	NOR	36,421	39,349	2,928	*9.50*	59.1	63.8	-4.7	*-8.0*
		SOU	25,232	22,305	2,927		40.9	36.2	4.7	*11.5*
Goosefish (*Lophius americanus*)	3,246,832	NOR	1,591,261	1,624,922	33,661	2.07	49.0	50.0	-1.0	-2.0
		SOU	1,655,571	1,621,910	33,661		51.0	50.0	1.0	2.0
Silver hake (*Merluccius bilinearis*)	4,606,490	NOR	876,514	950,975	74,461	3.23	19.0	20.6	-1.6	*-8.4*
		SOU	3,729,976	3,655,515	74,461		81.0	79.4	1.6	2.0
Red hake (*Urophycis chuss*)	458,731	NOR	142,190	145,968	3,778	1.65	31.0	31.8	-0.8	-2.6
		SOU	316,541	312,763	3,778		69.0	68.2	0.8	1.2

Table 23. Results of the Vessel Monitoring System (VMS) based stock area allocation compared to the stock area allocation based on the Vessel Trip Reports (VTR) reported statistical area for 2007. Relative difference is determined as % difference/VTR stock allocation; allocations ≥ 5.0% relative differences are italicized. Stock areas are Gulf of Maine (GOM), Georges Bank (GBK), southern New England/mid-Atlantic (SNE), northern (NOR), and southern (SOU). Note: allocations may not sum to 100 due to rounding.

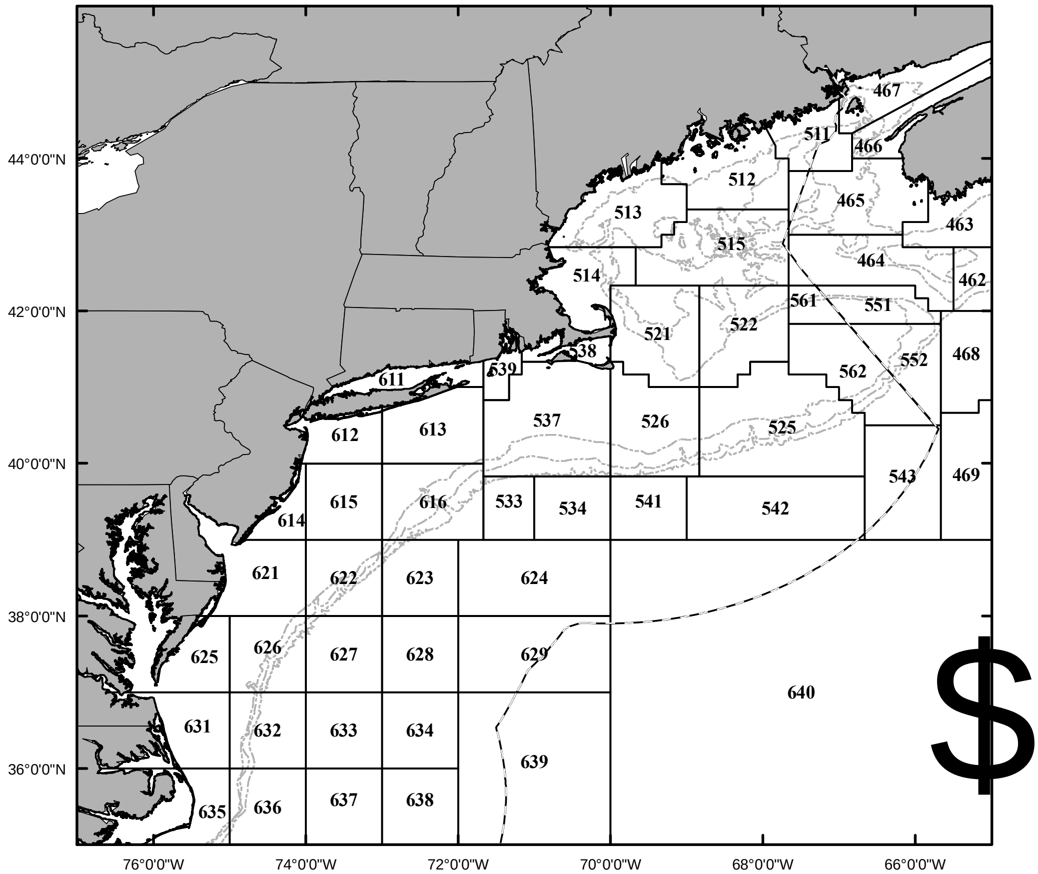
Species	Total species landings (kg)	Stock area	VTR landings allocation (kg)	VMS landings allocation (kg)	Δ landings allocation abs(kg)	$\sum\Delta_i$/total species landings (%)	VTR stock allocation (%)	VMS Stock allocation (%)	Difference (%)	Relative difference (%)
Atlantic cod	5,838,287	GBK	2,971,618	2,948,151	23,466	0.8	50.9	50.5	0.4	0.8
(*Gadus morhua*)		GOM	2,866,669	2,890,135	23,466		49.1	49.5	-0.4	-0.8
Haddock	3,013,511	GBK	2,475,073	2,471,087	3,985	0.3	82.1	82.0	0.1	0.2
(*Melanogrammus aeglefinus*)		GOM	538,438	542,423	3,985		17.9	18.0	-0.1	-0.7
Yellowtail flounder	1,623,035	GBK	1,107,416	1,128,478	21,062	2.6	68.2	69.5	-1.3	-1.9
(*Limanda ferruginea*)		GOM	376,016	356,443	19,574		23.2	22.0	1.2	*5.5*
		SNE	139,603	138,114	1,488		8.6	8.5	0.1	1.1
Winter flounder	2,172,096	GBK	766,057	713,963	52,094	4.8	35.3	32.9	2.4	*7.3*
(Pseudopleuronectes americanus)		GOM	193,425	204,320	10,895		8.9	9.4	-0.5	*-5.3*
		SNE	1,212,614	1,253,813	41,199		55.8	57.7	-1.9	-3.3
Windowpane flounder	144,231	NOR	110,327	110,067	260	0.4	76.5	76.3	0.2	0.2
(Scophthalmus aquosus)		SOU	33,904	34,164	260		23.5	23.7	-0.2	-0.8
Goosefish	2,969,033	NOR	1,106,535	1,094,480	12,056	0.8	37.3	36.9	0.4	1.1
(*Lophius americanus*)		SOU	1,862,497	1,874,553	12,056		62.7	63.1	-0.4	-0.6
Silver hake	5,749,198	NOR	1,045,749	1,065,613	19,865	0.7	18.2	18.5	-0.3	-1.9
(*Merluccius bilinearis*)		SOU	4,703,449	4,683,584	19,865		81.8	81.5	0.3	0.4
Red hake	544,902	NOR	106,960	105,305	1,655	0.6	19.6	19.3	0.3	1.6
(*Urophycis chuss*)		SOU	437,942	439,597	1,655		80.4	80.7	-0.3	-0.4

Table 24. Results of the Vessel Monitoring System (VMS) based stock area allocation compared to the stock area allocation based on the Vessel Trip Reports (VTR) reported statistical area for 2008. Relative difference is determined as % difference/VTR stock allocation; allocations ≥ 5.0% relative differences are italicized. Stock areas are Gulf of Maine (GOM), Georges Bank (GBK), southern New England/mid-Atlantic (SNE), northern (NOR), and southern (SOU). Note: allocations may not sum to 100 due to rounding.

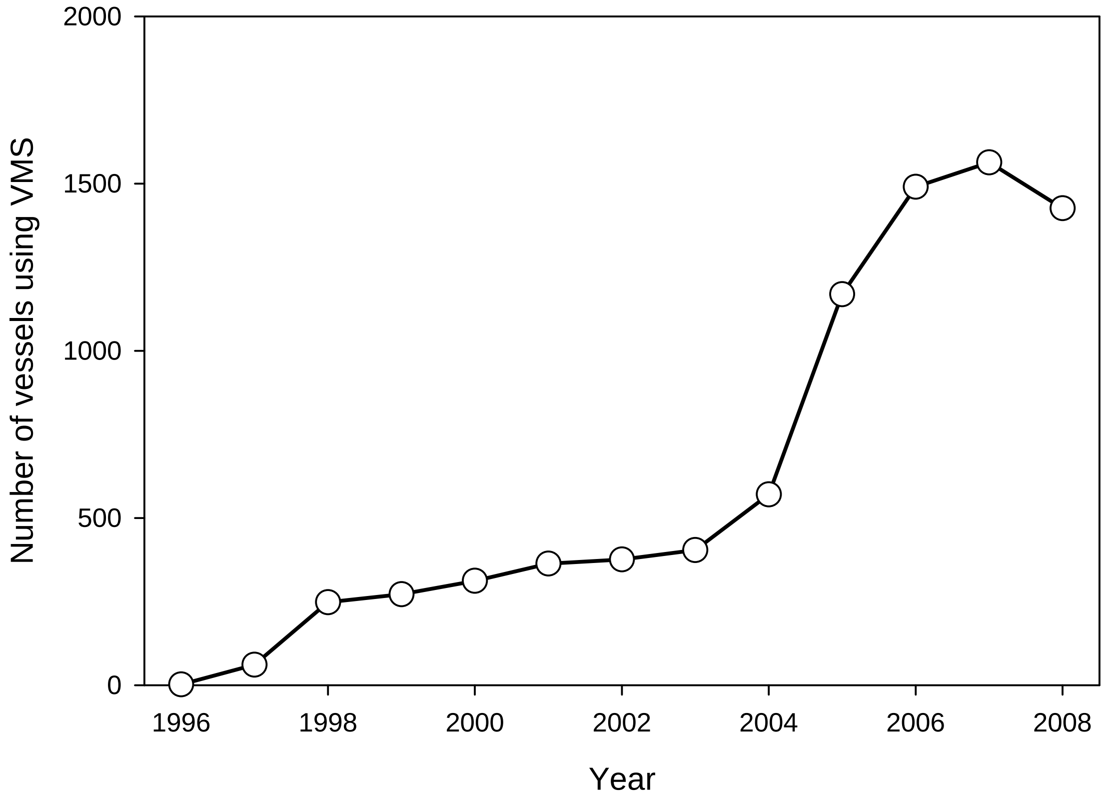
Species	Total species landings (kg)	Stock area	VTR landings allocation (kg)	VMS landings allocation (kg)	Δ landings allocation abs(kg)	$\sum\Delta_i$/total species landings (%)	VTR stock allocation (%)	VMS Stock allocation (%)	Difference (%)	Relative difference (%)
Atlantic cod	4,987,617	GBK	1,977,321	1,964,655	12,666	0.5	39.6	39.4	0.3	0.6
(*Gadus morhua*)		GOM	3,010,296	3,022,962	12,666		60.4	60.6	-0.3	-0.4
Haddock	4,072,033	GBK	3,801,155	3,748,015	53,140	2.6	93.3	92.0	1.3	1.4
(*Melanogrammus aeglefinus*)		GOM	270,879	324,018	53,140		6.7	8.0	-1.3	*-16.4*
Yellowtail flounder	1,239,577	GBK	772,304	770,172	2,132	0.3	62.3	62.1	0.2	0.3
(*Limanda ferruginea*)		GOM	358,242	358,411	169		28.9	28.9	0.0	0.0
		SNE	109,030	110,993	1,963		8.8	9.0	-0.2	-1.8
Winter flounder	1,875,233	GBK	915,033	849,254	65,779	7.0	48.8	45.3	3.5	*7.7*
(Pseudopleuronectes americanus)		GOM	187,557	193,399	5,843		10.0	10.3	-0.3	-3.0
		SNE	772,643	832,579	59,936		41.2	44.4	-3.2	*-7.2*
Windowpane flounder	59,340	NOR	33,564	31,550	2,014	6.8	56.6	53.2	3.4	*6.4*
(Scophthalmus aquosus)		SOU	25,776	27,789	2,014		43.4	46.8	-3.4	*-7.2*
Goosefish	1,791,932	NOR	428,672	445,051	16,379	1.8	23.9	24.8	-0.9	-3.7
(*Lophius americanus*)		SOU	1,363,260	1,346,881	16,379		76.1	75.2	0.9	1.2
Silver hake	3,801,904	NOR	616,304	633,309	17,005	0.9	16.2	16.7	-0.4	-2.7
(*Merluccius bilinearis*)		SOU	3,185,600	3,168,595	17,005		83.8	83.3	0.4	0.5
Red hake	535,765	NOR	105,091	105,101	10	0.0	19.6	19.6	0.0	0.0
(*Urophycis chuss*)		SOU	430,673	430,664	10		80.4	80.4	0.0	0.0

Figures

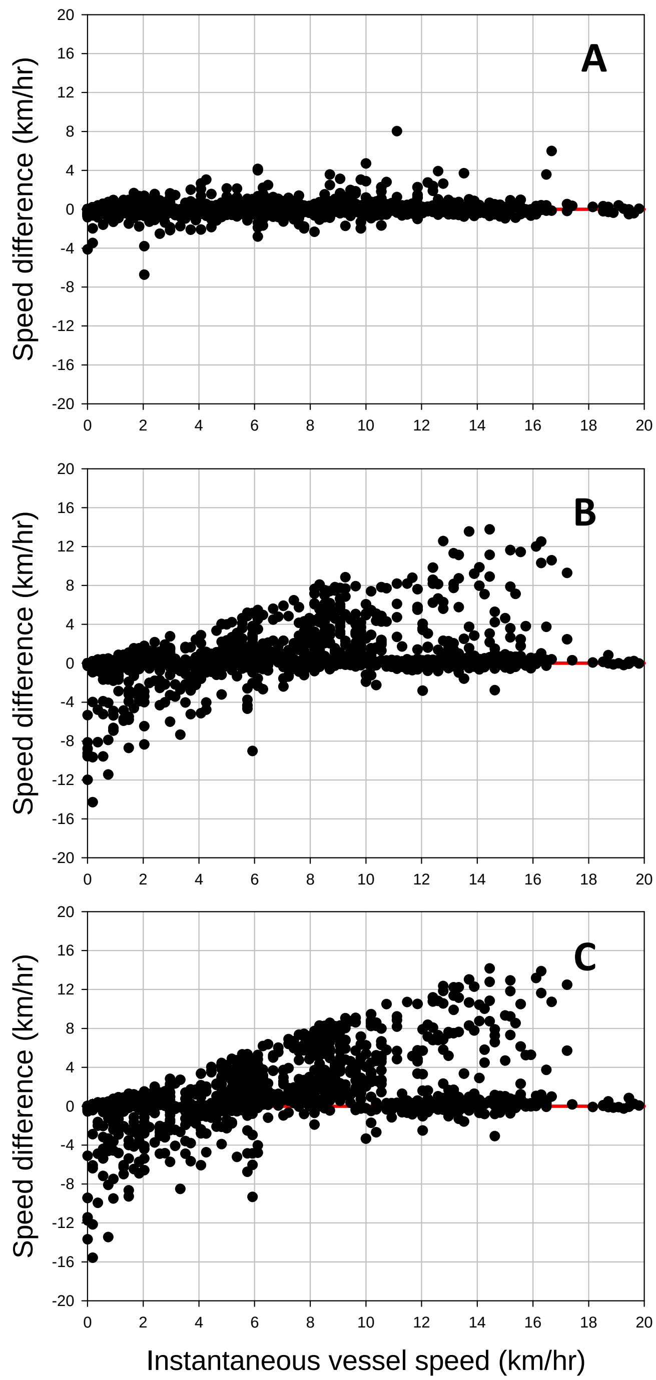
Palmer and Wigley - Figure 1.



Palmer and Wigley - Figure 2.



Palmer and Wigley – Figure 3.



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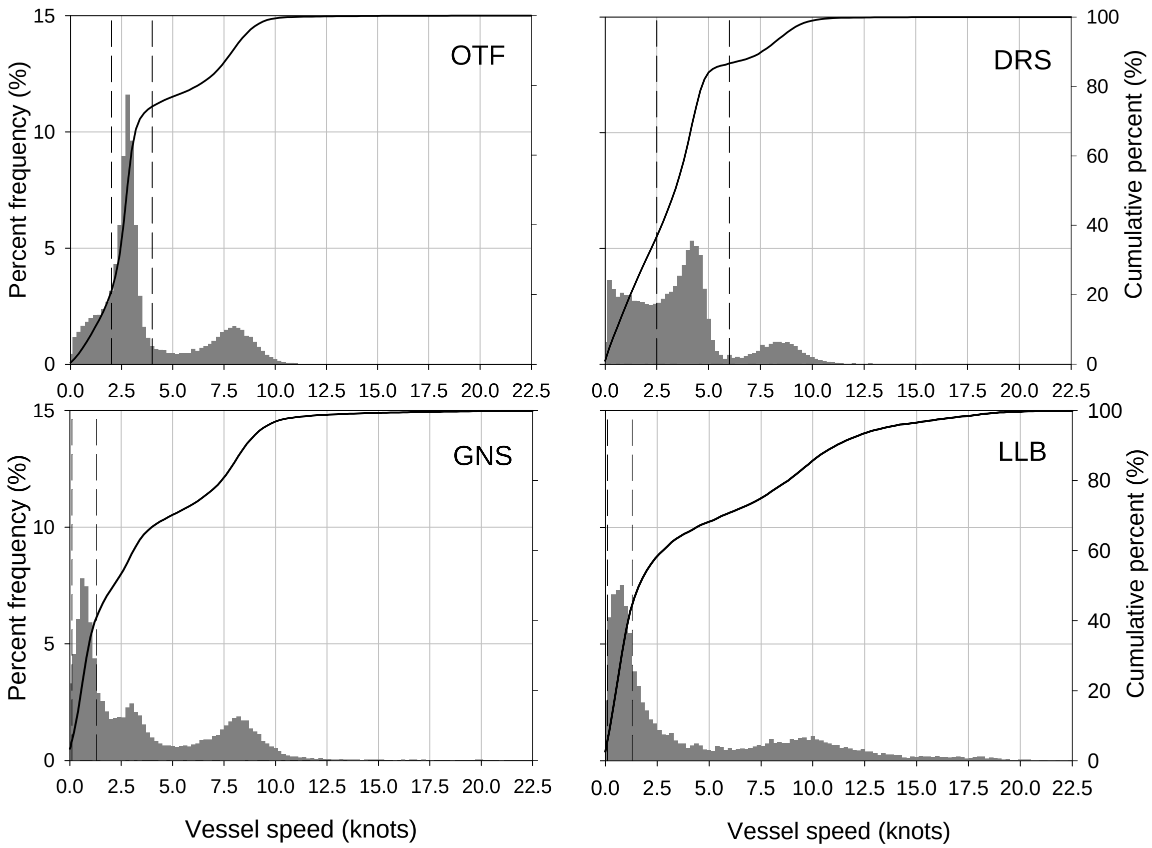

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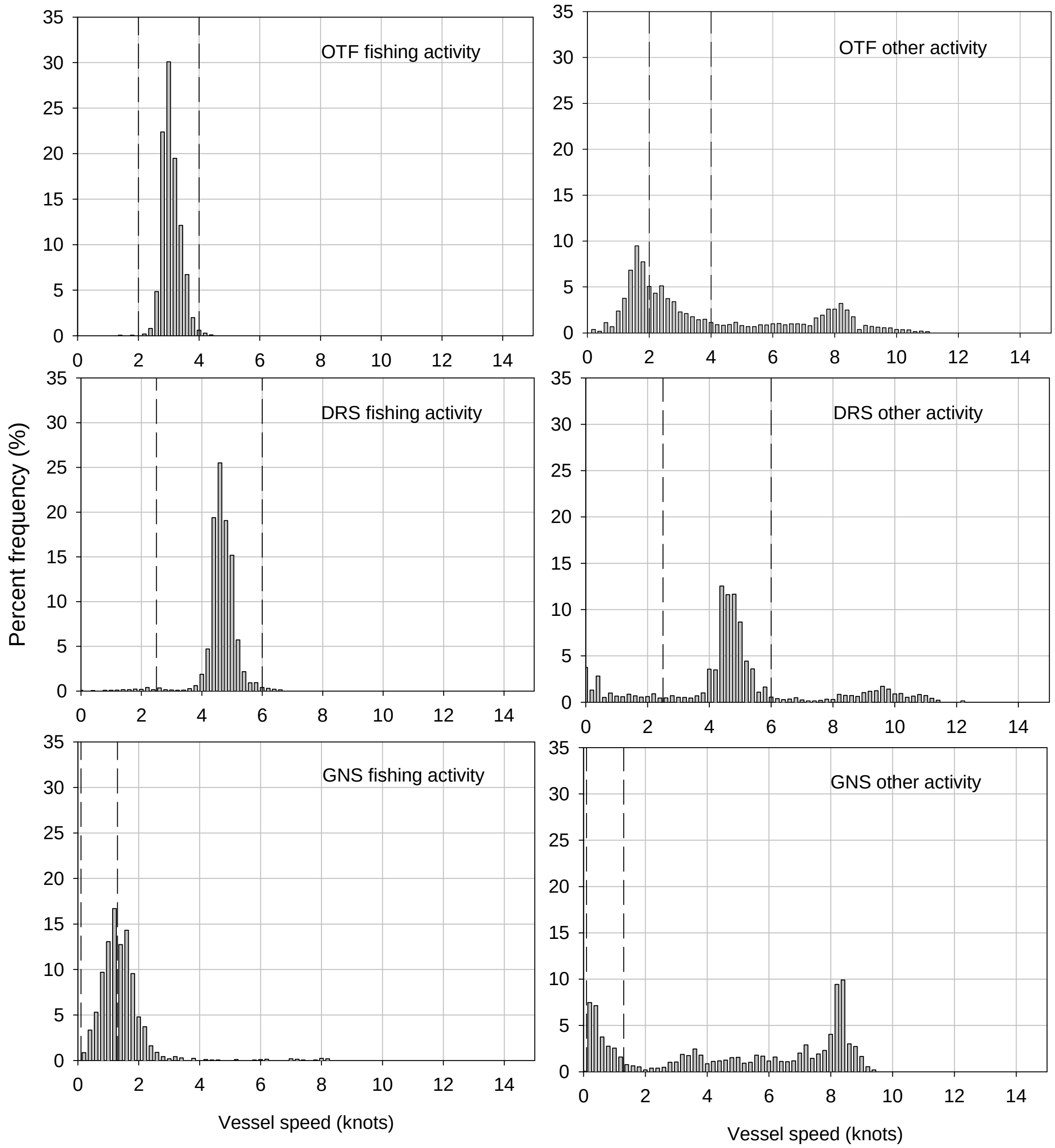

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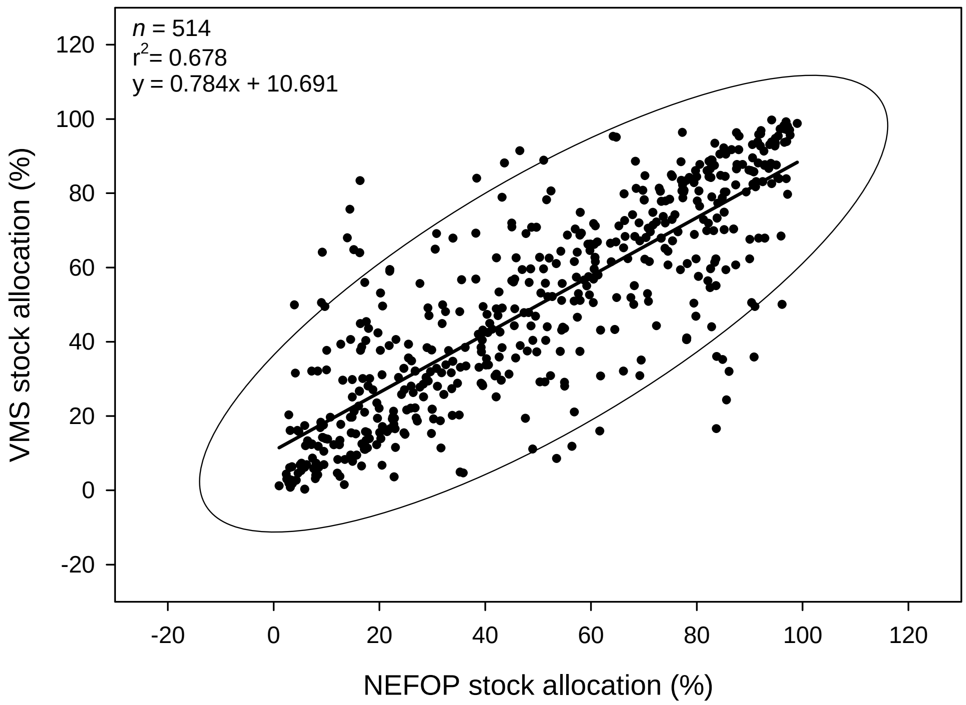

Figure 1. Statistical areas used for commercial fisheries data collection by the National Marine Fisheries Service in the Northeast Region. The 50, 100 and 500 fa bathymetric lines are shown in light gray and the U.S. Exclusive Economic Zone is indicated by the dashed black line.

Figure 2. Number of vessels using Vessel Monitoring System (VMS) in the northeast United States between 1998 and 2006.

Figure 3. Vessel speeds calculated from sequential GPS polling positions to the compared to a vessel's instantaneous speed recorded directly from the GPS unit. Plot A shows the comparison of the calculated average speed of a fishing vessel compared to the vessel's instantaneous speed when the VMS polling frequency is 1 position/minute. Plot B shows the effect when the VMS polling frequency is 1 position/30 minutes. Plot C shows the effect when the VMS polling frequency is 1 position/hour.

Figure 4. Percent frequency and cumulative percent distributions of average vessel speed (knots) as determined from Vessel Monitoring System (VMS) positions for vessels fishing fish bottom otter trawl (OTF), scallop dredge (DRS), sink gillnet (GNS) and benthic longline (LLB). The dashed lines represent the bounds used in this study to define fishing activity (OTF = 2.0 – 4.0 knots, DRS = 2.5 – 6.0 knots, GNS = 0.1 – 1.3 knots, LLB = 0.1 – 1.3 knots).

Figure 5. Percent frequency distribution of instantaneous vessel speed (knots) of vessels fishing fish bottom otter trawl gear (OTF), scallop dredge gear (DRS) and sink gillnet (GNS) characterized by both 'fishing' and 'other' activity. These data were collected using high-frequency polling of the vessel's global positioning unit (>1 observation/20 seconds) and represent the aggregate of multiple fishing trips. The dashed lines represent the bounds used in this paper to define fishing activity (OTF = 2.0 – 4.0 knots, DRS = 2.5 – 6.0 knots, GNS = 0.1 – 1.3 knots).

Figure 6. Comparison of 2005 Vessel Monitoring System (VMS) – Northeast Fisheries Observer Program (NEFOP) species stock allocations at the trip-level and associated 95 % confidence ellipse. Only those species-trip allocations where VMS and NEFOP-based methods agreed on the number of stock areas fished and the number of stock areas fished > 1 were compared.

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Industry-based Surv (GSCh)

Results of an Industry-Based Survey for Winter Flounder in the Great South Channel

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School for Marine Science and Technology (SMAST)

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Introduction

Between June and October of 2010, scientists at the School for Marine Science and Technology (SMAST) collaborated with members of the New Bedford otter trawl fleet to conduct an industry-based survey for winter flounder in the Great South Channel. The survey was composed of two components; biological survey and a mark-recapture experiment. The goals of the survey component were to provide better information on the relative abundance, geographical distribution, and demographic information for winter flounder in the Great South Channel. The goals of the tagging experiment were to utilize a robust design mark-recapture model to calculate an absolute estimate of winter flounder abundance and survival in the Great South Channel. The industry-based survey was designed to help inform the winter flounder stock assessment during a period when fishery dependent data sources may be limited for this resource. Another goal of the industry-based survey was to allow fishermen to actively participate in the research that influences the management of their fisheries.

Prior to the survey, a series of meetings was held with SMAST scientists and members of the New Bedford otter trawl fleet. During the meetings, fishermen identified areas within the Great South Channel where winter flounder are currently, and have historically, been abundant. Input from fishermen was used to define a study area for the survey (Figure 1), and to determine the best time of year to conduct the survey. SMAST scientists, fishermen, and net manufacturers collaborated to design a survey net that was suitable to fish for winter flounder in the Great South Channel.

Five vessels with experience fishing for winter flounder in the Great South Channel were chosen to participate in the industry-based survey. The characteristics of each vessel were considered, and measures were taken to select vessels with similar attributes (i.e., length, horsepower, gross registered tonnage).

Methods

Survey Planning and Design

The design of the survey was established between January and May of 2010, using input from members of the New Bedford otter trawl fleet. The study area ranged from just offshore of Chatham, MA, southward to the northeast portion of the Nantucket Lightship Closed Area. The eastern boundary of the survey area was Closed Area 1. Depth within the study area ranged from approximately 10 to 90 meters. The study area was divided into 132, nine square nautical mile grid cells (Figure 1), and the study site had a total area of 4,057.48 km^2.

Five survey trips were completed between June and October of 2010, and each trip ranged from nine to ten days in duration. A target of 64 survey tows was set for each trip. The survey was designed to enable the use of a robust design mark-recapture tagging model, to estimate winter flounder abundance and survival. Each survey trip was the primary sampling event, and there were four secondary sampling events within a trip. Each secondary sampling event consisted of 16 survey tows. Of the 16 tows, the location of 12 tows was chosen at random, and the location of four tows was chosen by the captain (Figure 2). For each secondary sampling event, the random point generation software of the Hawth's Tools extension for ArcGIS was used to generate 12 random points within the study site. The grid cells containing these 12 random points were then selected, and a tow was completed in each of the 12 grid cells during that secondary sampling event. A total of 64 survey tows were completed during each trip in June, July and August. On each trip, 48 tow locations were chosen at random, and 16 tow locations were selected by the captain. During the final two survey trips in September and October, three secondary sampling events (48 tows) were completed. During these months, 36 tow locations were chosen at random, and 12 tow locations were selected by the captain.

Each secondary sampling event was completed by traveling from north to south, and the captain and scientists worked together to determine the optimal order to complete the tows within a secondary sampling period. After each secondary sampling period was completed, the vessel steamed to the northern portion of the study area, and completed the next secondary sampling period, proceeding in a north to south direction.

Vessels

Five vessels with experience fishing for winter flounder in the Great South Channel were chosen to participate in the industry-based survey. Effort was taken to select vessels with similar characteristics, to ensure that survey results would be comparable between months. The characteristics of each vessel are shown below in Table 1.

Table 1. Characteristics of vessels that participated in the SMAST industry-based survey for winter flounder.

Vessel Name	Survey Month	Horsepower	Length (ft)	Gross Registered Tonnage	USCG Doc. Number
Seel	June	560	87	144	646423
Sasha Lee	July	678	82.3	129	909149
Sea Siren	August	520	70	140	600188
Iberia II	September	520	86	129	594749
United States	October	550	76.4	144	618882

Survey Tows

The captain chose the starting location of each survey tow within the designated grid cell, and the direction of the tow was left to the discretion of the captain. The tow time and vessel position were recorded using FLDRS, the Northeast Fisheries Science Center study fleet software, connected to a handheld GPS. The start of the tow was marked when the net was deployed and the winches were locked. The end of the tow was recorded when the winches were engaged to retrieve the net. Captains were instructed to complete tows in a straight line, without turning the vessel, whenever possible. The captain was asked to maintain a tow speed of roughly 3 knots, although this speed was not always attainable due to strong currents in the study site. The captain determined the amount of warp set on each tow. The amount of warp set during each tow was recorded in an Access database.

The target duration for a survey tow was 30 minutes, and the minimum acceptable tow duration was 20 minutes. On some occasions, tows were cut short due to gear problems (i.e., net hanging down) or excessive amounts of spiny dogfish bycatch.

Survey tows that were less than 20 minutes in duration were repeated within the same grid cell. Multiple attempts were made to complete each survey tow within the assigned grid cell. However, when it was not possible to complete a survey tow within the designated grid cell, an adjacent grid cell was chosen, and the survey tow was completed within that cell. If damage to the net occurred during a tow (i.e. hole in the net), the tow was repeated within the same grid cell. If a tow was not able to be completed in a grid because of the presence of fixed gear, another grid cell in close proximity was selected.

Excessive amounts of spiny dogfish bycatch were a problem during some survey tows. In some instances, the net had to be opened to release spiny dogfish, before the net could be brought on board. It is likely that a portion of the flounder captured during these tows were also released from the net along with the dogfish. Therefore, the exact weight of winter flounder caught during the tow was unknown. Of the 288 survey tows that were completed, the net had to be opened due to dogfish bycatch on 18 tows. Data from these 18 tows were not included in the analysis of winter flounder catch, distribution, or area swept biomass estimates.

Catch Sampling Protocols

After the survey tow was completed, the net was brought on board and the catch was dumped into a checker pen. All winter flounder were sorted from the catch by hand, and placed in holding tanks with fresh seawater. The weight of all other species caught in each tow was estimated by SMAST technicians, and recorded in an Access database. All species except winter flounder were thrown overboard as quickly as possible to minimize mortality.

The total length of each winter flounder was measured to the nearest centimeter, and any relevant comments were recorded for each flounder. The biomass of winter flounder (kg) caught on each survey tow was calculated by using the length-weight relationship for winter flounder captured on the NEFSC annual spring bottom trawl survey (Wigley et al., 2003):

$$\ln \text{weight (kg)} = -11.4718 + (3.0431 * \ln \text{length (cm)})$$

Survey tows ranged from 20 to 40 minutes in duration. In order to account for this variability, a tow duration ratio was calculated and winter flounder catches were adjusted to a standard tow length of 30 minutes. The tow duration ratio was calculated as follows:

$$\text{Tow duration ratio} = 30 \text{ minutes/observed tow time in minutes}$$

For each survey tow, winter flounder catches were standardized to a 30 minute tow duration using the tow duration ratio as follows:

$$\text{Standardized winter flounder catch (kg)} = \text{Observed winter flounder catch (kg)} * \text{tow duration ratio}$$

Tagging Protocols

The condition of each winter flounder was assessed using the protocols developed by Cadrin (2006). Each flounder that was deemed to be in “good” or “excellent” condition was double tagged with individually numbered plastic t-bar anchor tags (Figure 3), or tagged using a Peterson disc tag. Following tagging, each flounder was quickly released back to the water. A total of 50 dead winter flounder were retained during each survey trip, and brought back to the lab at SMAST for use in a stock composition analysis study.

The tagging experiment was designed to enable the use of a 'robust design' mark-recapture model (Pollock, 1982), to estimate winter flounder abundance and survival in the Great South Channel. The robust design involves a series of short-term, closed population experiments, which are used to estimate abundance. The short-term experiments are nested within open population models that are used to calculate survival using Jolly-Seber estimation (Figure 4). Each survey trip constituted the primary sampling event, and four groups of 16 survey tows were used as the secondary sampling event. The population was assumed to be closed during each survey trip, and open during the periods between survey trips. Prior to the start of the survey, a series of model simulations were performed to determine the appropriate number of survey trips and tag releases that would be needed to support the analysis.

Survey Nets

Two survey nets were constructed by Reidar's Manufacturing in Fairhaven, MA (Figure 5). The nets were 2-seam "flat" nets designed for targeting winter flounder in hard bottom. The nets were constructed with 4 mm euroline netting, with 4.5 inch mesh in the net body and codend. The fishing line was 80 feet, and the headrope was 60 feet. The groundgear was constructed with rock hopper discs with floppies in-between the rock hoppers. The center portion of the groundgear had 21 inch rock hopper discs that tapered to 18 inches and then 16 inch discs at the wings. There were 60 eight inch center hole floats on the headrope. The bridles were 30 feet in length. The top bridle was wire and the bottom bridle was chain. No groundcables were used on the study nets, which is consistent with the net configuration used by New Bedford fishermen in the study area. The dimensions of the net were designed to be appropriate for the size and horsepower of the vessels that participated in the survey.

A model of the survey net was tested in the flume tank at Memorial University in Newfoundland. The performance of the net was evaluated in the flume tank, and slight modifications to the original net design were made. The configuration of the net was monitored during survey tows using e-Sonar and Netmind net mensuration equipment. The equipment measured the doorspread, wingspread, and headrope height during each survey tow. If the net was not fishing at an optimal configuration, the captain could modify the tow speed or amount of warp to adjust the dimensions of the survey net. Placement of sensors was consistent with recommendations from the ICES Study Group on Survey Trawl Standarisation (ICES, 2006). The headrope sensor was placed in the center of the headrope, the wing sensors were placed in front of the wings tips attached to the upper bridge, and the door sensors were typically welded to the center of the doors, although the position of the door sensors varied depending on type of door used.

Length Frequency

The size structure of winter flounder captured during each leg of the survey was examined. The length frequency of winter flounder captured on the industry-based survey was compared to the length frequency of winter flounder captured on the NEFSC spring and fall survey in strata 1250 and 3550 between 2000 and 2009. A Kolmogorov-Smirnov test was conducted to look for differences in the size structure of winter flounder caught on the two surveys (Sokal and Rohlf, 2001).

The fishermen participating in the survey stated that they typically catch larger winter flounder in the deeper waters of the Great South Channel. To test this hypothesis, the length frequency distributions of winter flounder caught on “shallow” and “deep” tows was examined. The average depth sampled during the survey was 52 meters. The size distribution of winter flounder caught during tows conducted in waters < 52 meters were included in the “shallow” group, and flounder caught in tows > 52 meters were included in the “deep” group. A Kolmogorov-Smirnov test was conducted to look for differences in the size structure of winter flounder in deep and shallow tows (Sokal and Rohlf, 2001).

Area Swept Calculations

Estimates of winter flounder density (kg/km^2) and winter flounder biomass were calculated by examining the catch of winter flounder and the area sampled by the survey net, for the 270 valid tows that were completed during the industry-based survey. The net mensuration data from these 270 survey tows were audited for outliers and data properties were examined. Net mensuration data was audited based on recommendations from the ICES Study Group on Survey Trawl Standarisation (ICES, 2006). Data was excluded based on quantiles and observed values from a test model put in the flume tank at Memorial University. Headrope data was trimmed to between the 0% quantile and the 75% quantile. The 0% quantile was used because the sensor’s minimum reading is 2.2 meters. Wing data was trimmed to the 25% quantile and 21 meters, which was the optimal wingspread observed in the flume tank for the net. The door data was trimmed to between the 25% and the 75% quantiles. The mean doorspread, wingspread and headrope values were calculated for each tow. The mean doorspread and wingspread measurements were converted from meters to kilometers. Estimates of doorspread and wingspread were not available for every tow, due to technical problems with the net mensuration equipment. In these cases, the mean doorspread or wingspread value observed during that trip was used in the area swept calculation because there were significant differences in the mean value on the trip level. During the fourth survey trip, completed in September, the wing sensors were not properly attached to the survey net. For all survey tows that were conducted in September (n=35), the mean wingspread observed during trips 1, 2, 3 and 5 (mean = 0.014 km) was used to calculate area swept.

Throughout each trip, the vessel position (latitude and longitude), speed and course of were recorded electronically every 30 seconds using the GPS polling function of the FLDRS fishery monitoring software. Fishing activity was assumed to occur when the vessel speed was between 2.0 and 4.0 knots, based on the results of Palmer and Wigley (2007), which found that 99.2% of otter trawl fishing activities occur at this range of speed. Therefore, the tow speed data was trimmed and observations <2.0 knots or >4.0 knots were excluded from the analysis. The trimmed data were used to calculate the mean speed (km/hour) for each survey tow. The duration of each tow was converted from minutes to a fraction of an hour for area swept calculations.

The total area swept (km^2) by the trawl doors was calculated for each tow using the following formula:

$$\textbf{Area swept (km}^2\textbf{) = doorspread (km) * tow duration (hr) * tow speed (km/hr)}$$

Similarly, the total area swept by the wings of the net during each survey tow was calculated using the following formula:

$$\textbf{Area swept (km}^2\textbf{) = wingspread (km) * tow duration (hr) * tow speed (km/hr)}$$

Area swept calculations were used to calculate the density of winter flounder (kg/km^2) observed during each survey tow. The following formula was used to calculate the density of winter flounder observed during each tow. The mean density of winter flounder observed during each survey trip was also calculated:

$$\textbf{Winter flounder density (kg/km}^2\textbf{) = winter flounder catch (kg)/area swept (km}^2\textbf{)}$$

Each grid cell in the study area had an area of 30.74 km^2, and a total of 132 grid cells were present within the study area. The study site encompassed a total area of 4,057.48 km^2. Estimates of winter flounder density were used to derive an estimate of the winter flounder biomass sampled during each tow, using the following equation:

$$\textbf{Winter flounder biomass (kg) = winter flounder density (kg/km}^2\textbf{) * 4,057.48 km}^2$$

The biomass estimate derived for each survey tow was then used to calculate a mean biomass estimate for each of the five trips. The biomass estimate for each trip was converted from kilograms to metric tons.

The catchability (q) of the survey net is unknown. To investigate the effect of catchability on estimates of winter flounder density and biomass, a series of calculations were made using catchability estimates ranging from 0.1 to 1.0. The density of winter flounder was calculated using the following equation:

$$\textbf{Winter flounder density (kg/ km}^2\textbf{) = winter flounder catch (kg)/area swept (km}^2\textbf{) * (1/q)}$$

The exploitable biomass of winter flounder within the study area was estimated. For these estimations, the biomass of winter flounder $\geq$ 30cm captured during each survey tow was calculated. The exploitable biomass of winter flounder in the study area was estimated using both the doorspread and wingspread to estimate area swept.

$$\textbf{Density of exploitable winter flounder (kg/km}^2\textbf{) = catch of winter flounder} \geq \textbf{30cm / area swept (km}^2\textbf{)}$$

$$\textbf{Exploitable biomass (kg) = Density of exploitable flounder (kg/km}^2\textbf{) * 4,057.48 km}^2$$

Depletion Experiments

During the final two survey trips, in September and October, a series of depletion experiments were conducted. The goal of the depletion experiments was to calculate an estimate of the survey net catchability, and to estimate the biomass of winter flounder in the survey area.

Winter flounder catch rates from the first survey trips suggested that catchability was greater at night than during the day. Captains also indicated that the winter flounder fishery in the study area is typically conducted at night. Therefore, depletion experiments were conducted both during the day and night to examine diel differences in catchability. Depletion experiments during the day were completed between sunrise and sunset, and experiments conducted at night were completed between sunset and sunrise.

Depletion experiments could be conducted in grid cells that had been previously sampled during survey tows on that trip, or in a cell that the captain selected based on experience. The experiments were conducted in grid cells that were observed to have high abundances of winter flounder, and which appeared to have suitable bottom to conduct multiple tows while limiting the bycatch of certain species like spiny dogfish. Tows completed during depletion experiments had a target duration of 20 minutes. However, actual tow durations varied between 7 and 34 minutes. Therefore, winter flounder catch rates were standardized (# of flounder caught per minute) to facilitate comparisons of catch rates between tows. Captains were instructed to tow the net over the same bottom as accurately as possible during each tow in a depletion experiment, and each tow was made in the same direction during a depletion experiment if possible. The direction of the tidal current would occasionally prohibit returning to the starting point of a depletion tow. When this occurred, the vessel began the next depletion tow at the end point of the previous tow. Between four and eight tows were completed during each depletion experiment. Protocols determining when to stop depletion experiments differed between trips four and five. During the fourth trip, the protocol dictated that the depletion experiment should be ended when a significant linear regression was found between the catch rate (# flounder per minute) and the cumulative catch. On the fifth trip, the protocol was adjusted to account for the potential effect of the tidal current. The protocol for the fifth trip was to complete as many tows as possible during each depletion experiment.

During depletion experiments, the number of winter flounder caught on each tow was counted, and each flounder was measured to the nearest centimeter. As time permitted, winter flounder were either double or single tagged with individually numbered plastic t-bar tags. The catches of winter flounder were plotted, with the number of winter flounder caught per minute on the y-axis and cumulative winter flounder catch on the x-axis. Linear regression was used to determine if there was a significant relationship between catch rates and the cumulative catch. During depletion experiments, the slope of the regression line can be used to generate an estimate of the catchability of the net.

Results

Winter Flounder Catches

A total of 270 valid survey tows were completed during the five trips between June and October (Figure 6). Observed winter flounder catches were analyzed to investigate the monthly distribution of winter flounder in the Great South Channel. The standardized mean winter flounder catch (kg) per survey tow is shown in Table 2.

Table 2. Mean standardized winter flounder catches (kg) for survey tows conducted between June and October of 2011.

	Number of tows	Mean catch per tow (kg)	St. Dev.	Maximum catch (kg)	# of tows with no winter flounder
Trip 1	64	36.76	43.89	189.15	3
Trip 2	61	22	50.27	308.44	8
Trip 3	64	45.79	58.59	276.24	2
Trip 4	35	33.31	76.11	405.51	9
Trip 5	46	28.88	61.13	382.38	5
Survey Mean		**33.35**			

The largest mean winter flounder catches were observed during the month of August. Winter flounder were widely distributed throughout the study area during this time, and flounder were captured during 62 of the 64 survey tows that were conducted. The smallest mean winter flounder catches were observed in July, when an average of 22.0 kg of winter flounder was captured per 30 minute tow. The single largest catch of winter flounder occurred in September, when 405.5 kg of winter flounder were caught during a survey tow.

During each trip, 75% of all survey tows occurred in grid cells that were chosen at random, and 25% were conducted in grid cells were chosen by the captain. Generally, winter flounder catches were greater when the location of the tow was selected by the captain. The mean winter flounder catches observed for random and fishermen selected tow locations is shown below in Table 3.

Table 3. Mean standardized catch of winter flounder (kg) observed during random and fishermen selected tows for each trip during the winter flounder industry-based survey.

	Random tows		Fishermen selected tows	
	n	mean	n	mean
Trip 1	48	23.66	16	76.06
Trip 2	46	17.71	15	35.17
Trip 3	48	29.03	16	96.08
Trip 4	29	21.43	6	90.72
Trip 5	35	26.79	11	35.55
Survey Mean		**23.72**		**66.71**

During the survey, 129 tows were completed during the day, and 141 tows were completed at night. Winter flounder catches were typically higher during the nighttime than during the day. The average catch of winter flounder was greater at night than during the day in each month, with the exception of August. The average winter flounder catch observed during the day and night for each survey trip is shown below in Table 4.

Table 4. The mean standardized catch of winter flounder (kg) observed during the day and at night during each of the survey trips that was completed.

	Day		Night	
	n	mean	n	mean
Trip 1	38	27.31	26	50.58
Trip 2	32	10.83	29	34.33
Trip 3	33	55.43	31	35.54
Trip 4	13	18.11	22	42.29
Trip 5	13	22.26	33	31.49
Survey Mean		**26.79**		**38.85**

The distribution of standardized winter flounder catches observed during each survey trip is shown in Figures 6 though 10. In June (Figure 7), winter flounder are most numerous in the western portion of the study site. During July (Figure 8), winter flounder were again numerous in the western portion of the study site. The distribution of winter flounder appeared to shift slightly eastward between June and July. By August (Figure 9), winter flounder are most abundant in the eastern portion of the study area. The biomass of winter flounder appears to have shifted substantially between June and August, as very few flounder were captured in the western portion of the study area in August. The distribution of winter flounder in September (Figure 10) is similar to the distribution observed in August. Winter flounder are most numerous in the deeper waters, near the eastern boundary of the study area. However, fewer survey tows were made in September (n=35) relative to other months (n= 46 to 64). Finally, in October (Figure 11), winter flounder were again numerous in the eastern portion of the study area. In October, the center of distribution appears to have shifted slightly to the north.

Area Swept Calculations

The number of tows in which actual net mensuration data was used to calculate the mean doorspread and wingspread is shown in Table 5. Problems with the net mensuration equipment were common during the survey. Problems with the door sensors arose during the first survey trip in June. The wing sensors were damaged during the fourth tow of trip 3, and wingspread data was unavailable for tows 4 through 64. In addition, the wing sensors were not properly placed on the survey net during trip 4.

Table 5. Number of tows during each survey trip where the actual doorspread and wingspread was calculated from observations recorded by the net mensuration equipment.

		Doorspread			Wingspread		
Trip	n	# tows with actual data	# of tows with estimated data	% of tows with actual data	# tows with actual data	# of tows with estimated data	% of tows with actual data
1	64	11	53	17.2%	62	2	96.9%
2	61	50	11	82.0%	43	18	70.5%
3	64	47	17	73.4%	3	61	4.7%
4	35	21	14	60.0%	0	35	0.0%
5	46	31	15	67.4%	27	19	58.7%
Total	270	160	110	**59.3%**	135	135	**50.0%**

The average area swept by the net during each survey tow is shown below in Table 6. Mean estimates of the area swept by the wings of the net were calculated for each survey. The mean area swept per tow observed during the industry-based survey

($0.0110\ nm^2$) is in close agreement to the average area swept per tow by the R/V Albatross during the NEFSC spring and fall groundfish surveys ($0.0112\ nm^2$; Groundfish Plan Development Team, 2010). The mean area swept per tow observed on the industry-based survey ($0.110\ nm^2$) was greater than the mean area swept per tow by the R/V Bigelow during the NEFSC spring and fall groundfish surveys ($0.007\ nm^2$; Groundfish Plan Development Team, 2010).

Table 6. Mean area swept per tow during the industry-based survey for winter flounder in the Great South Channel. Estimates of area swept were calculated using both the actual and averaged wingspread values for each survey tow.

	Mean area swept/tow (km^2)	Mean area swept/tow (nm^2)	Tow area/tow footprint
Trip 1	0.039	0.011	103797
Trip 2	0.041	0.012	99737
Trip 3	0.043	0.012	95174
Trip 4	0.033	0.010	124390
Trip 5	0.034	0.010	119739
Survey Mean	**0.038**	**0.011**	**107392**

The mean density (kg/km^2) and biomass (kg) of winter flounder estimated to be present in the study area during each month of the survey was calculated. Density and biomass estimates were made using both the doorspread and wingspread to estimate the area swept during each survey tow. A conservative catchability coefficient (q) of 1 was assumed during the calculations. The results are shown below in Table 7.

Table 7. Mean estimates of winter flounder density (kg/km^2) and biomass (kg) for each of the five survey trips that were completed between June and October, 2010. Density and biomass estimates were calculated using both the doorspread and wingspread for each tow.

	Doorspread			Wingspread		
Trip	Density (kg/km^2)	Biomass (kg)	Biomass (mt)	Density (kg/km^2)	Biomass (kg)	Biomass (mt)
1	571.5	2318809.9	2281.7	1027.8	4170209.0	4103.5
2	299.0	1213008.2	1193.6	551.8	2238787.9	2203.0
3	632.5	2566400.1	2525.3	1089.5	4420512.9	4349.8
4	557.1	2260306.3	2224.1	1007.0	4085776.0	4020.4
5	507.1	2057692.5	2024.8	937.5	3803968.5	3743.1
Survey Mean	511.5	2083243.4	**2049.9**	922.7	3743850.9	**3683.9**

The mean density (kg/km^2) of winter flounder that was observed during each trip is shown below in Table 8. In these calculations, the mean doorspread observed during each tow was used to calculate the area swept during the tow. A range of catchability coefficients were used to determine the sensitivity of winter flounder density estimates to the catchability coefficient that was assumed for the survey net.

Table 8. Estimates of winter flounder density (kg/km^2) assuming a range of catchability values. The mean doorspread observed during each tow was used in area swept calculations.

	Density of winter flounder (kg/km^2)									
	q=1	q=0.9	q=0.8	q=0.7	q=0.6	q=0.5	q=0.4	q=0.3	q=0.2	q=0.1
Trip 1	571.5	635.0	714.4	816.4	952.5	1143.0	1428.7	1905.0	2857.4	5714.9
Trip 2	299.0	332.2	373.7	427.1	498.3	597.9	747.4	996.5	1494.8	2989.6
Trip 3	632.5	702.8	790.6	903.6	1054.2	1265.0	1581.3	2108.4	3162.6	6325.1
Trip 4	557.1	619.0	696.3	795.8	928.5	1114.1	1392.7	1856.9	2785.4	5570.7
Trip 5	507.1	563.5	633.9	724.5	845.2	1014.3	1267.8	1690.5	2535.7	5071.4
Survey Mean	**513.4**	**570.5**	**641.8**	**733.5**	**855.7**	**1026.9**	**1283.6**	**1711.4**	**2567.2**	**5134.3**

The mean biomass of winter flounder that was observed during each trip is shown below in Table 9. A range of catchability values were used to determine the sensitivity of biomass calculations to the catchability coefficient that was assumed for the survey net.

Table 9. Estimates of winter flounder biomass (kg) assuming a range of catchability values. The mean doorspread observed during each tow was used in area swept calculations.

	Biomass (mt)									
	q=1	q=0.9	q=0.8	q=0.7	q=0.6	q=0.5	q=0.4	q=0.3	q=0.2	q=0.1
Trip 1	2281.7	2535.2	2852.1	3259.6	3802.8	4563.4	5704.3	7605.7	11408.5	22817.1
Trip 2	1193.6	1326.2	1492.0	1705.1	1989.3	2387.2	2984.0	3978.7	5968.0	11936.0
Trip 3	2525.3	2805.9	3156.7	3607.6	4208.9	5050.7	6313.3	8417.8	12626.7	25253.4
Trip 4	2224.1	2471.3	2780.2	3177.3	3706.9	4448.3	5560.4	7413.8	11120.7	22241.4
Trip 5	2024.8	2249.7	2531.0	2892.5	3374.6	4049.5	5061.9	6749.2	10123.8	20247.7
Survey Mean	**2049.9**	**2277.7**	**2562.4**	**2928.4**	**3416.5**	**4099.8**	**5124.8**	**6833.0**	**10249.6**	**20499.1**

Estimates of mean winter flounder density (kg/km^2) calculated for each trip is shown below in Table 10. The calculations were made using the mean wingspread observed during each tow to calculate area swept. A range of catchability values were used to determine the sensitivity of winter flounder density estimates to the assumed catchability.

Table 10. Estimates of winter flounder density assuming a range of catchability values. The mean wingspread observed during each tow was used in area swept calculations.

	Density of winter flounder (kg/km^2)									
	q=1	q=0.9	q=0.8	q=0.7	q=0.6	q=0.5	q=0.4	q=0.3	q=0.2	q=0.1
Trip 1	1027.8	1142.0	1284.7	1468.3	1713.0	2055.6	2569.5	3425.9	5138.9	10277.8
Trip 2	551.8	613.1	689.7	788.2	919.6	1103.5	1379.4	1839.2	2758.8	5517.7
Trip 3	1089.5	1210.5	1361.8	1556.4	1815.8	2178.9	2723.7	3631.6	5447.4	10894.7
Trip 4	1007.0	1118.9	1258.7	1438.5	1678.3	2013.9	2517.4	3356.6	5034.9	10069.7
Trip 5	937.5	1041.7	1171.9	1339.3	1562.5	1875.0	2343.8	3125.1	4687.6	9375.2
Survey Mean	**922.7**	**1025.2**	**1153.4**	**1318.1**	**1537.8**	**1845.4**	**2306.8**	**3075.7**	**4613.5**	**9227.0**

Estimates of mean winter flounder biomass calculated for each trip are shown below in Table 11. These calculations were made using the mean wingspread observed during each tow to calculate area swept. A range of catchability values were used to determine the sensitivity of winter flounder biomass estimates to the assumed catchability.

Table 11. Estimates of winter flounder biomass assuming a range of catchability values. The mean wingspread observed during each tow was used in area swept calculations.

	Biomass (mt)									
	q=1	q=0.9	q=0.8	q=0.7	q=0.6	q=0.5	q=0.4	q=0.3	q=0.2	q=0.1
Trip 1	4103.5	4559.4	5129.4	5862.1	6839.1	8207.0	10258.7	13678.3	20517.4	41034.9
Trip 2	2203.0	2447.7	2753.7	3147.1	3671.6	4405.9	5507.4	7343.2	11014.8	22029.7
Trip 3	4349.8	4833.1	5437.2	6214.0	7249.6	8699.6	10874.5	14499.3	21748.9	43497.8
Trip 4	4020.4	4467.1	5025.5	5743.4	6700.7	8040.8	10051.0	13401.3	20102.0	40204.0
Trip 5	3743.1	4159.0	4678.9	5347.3	6238.5	7486.2	9357.8	12477.0	18715.5	37431.1
Survey Mean	**3683.9**	**4093.3**	**4604.9**	**5262.8**	**6139.9**	**7367.9**	**9209.9**	**12279.8**	**18419.7**	**36839.5**

The exploitable biomass of winter flounder within the study area was estimated. The weight of winter flounder ≥ 30cm caught during each tow was used in the biomass calculations. The density of exploitable biomass was calculated using both the doorspread and wingspread to estimate area swept. Estimates of total biomass and exploitable biomass are shown in Table 12. Between 90.44% and 94.97% of the winter flounder biomass in the study area is composed of winter flounder which are considered to be exploitable by the fishery (≥ 30cm). The catchability of the survey net was assumed to be 100% (q =1) in these calculations.

Table 12. Estimates of exploitable and total biomass of winter flounder for each survey trip. Biomass was estimated using both the doorspread and the wingspread in area swept calculations. Calculations were made assuming a catchability coefficient of 1.

	Doorspread		Wingspread		
	Exploitable biomass (mt)	Total biomass (mt)	Exploitable biomass (mt)	Total biomass (mt)	% Exploitable Biomass
Trip 1	2086.0	2281.7	3755.2	4103.5	91.47%
Trip 2	1084.8	1193.6	2002.1	2203.0	90.88%
Trip 3	2398.3	2525.3	4130.8	4349.8	94.97%
Trip 4	2010.6	2224.1	3637.5	4020.4	90.44%
Trip 5	1909.9	2024.8	3535.2	3743.1	94.39%
Survey Mean	**1897.9**	**2049.9**	**3412.2**	**3683.9**	**92.60%**

Estimates of exploitable biomass were calculated assuming a range of catchability values between 0.1 and 1.0. Exploitable biomass estimates were calculated using both the doorspread (Table 13) and wingspread (Table 14) to calculate the area swept during each tow.

Table 13. Estimates of exploitable biomass assuming a range of values for q. The doorspread observed during each tow was used to calculate of area swept.

	Exploitable Biomass (mt)									
	q=1	q=0.9	q=0.8	q=0.7	q=0.6	q=0.5	q=0.4	q=0.3	q=0.2	q=0.1
Trip 1	2086.0	2317.8	2607.5	2980.0	3476.6	4172.0	5215.0	6953.3	10429.9	20859.8
Trip 2	1084.8	1205.4	1356.0	1549.8	1808.0	2169.7	2712.1	3616.1	5424.1	10848.3
Trip 3	2398.3	2664.8	2997.9	3426.1	3997.1	4796.6	5995.7	7994.3	11991.4	23982.9
Trip 4	2010.6	2234.0	2513.2	2872.3	3351.0	4021.2	5026.5	6702.0	10052.9	20105.9
Trip 5	1909.9	2122.1	2387.4	2728.5	3183.2	3819.8	4774.8	6366.4	9549.6	19099.2
Survey Mean	**1897.9**	**2108.8**	**2372.4**	**2711.3**	**3163.2**	**3795.8**	**4744.8**	**6326.4**	**9489.6**	**18979.2**

Table 14. Estimates of exploitable biomass assuming a range of values for q. The wingspread observed during each tow was used to calculate of area swept.

	Exploitable Biomass (mt)									
	q=1	q=0.9	q=0.8	q=0.7	q=0.6	q=0.5	q=0.4	q=0.3	q=0.2	q=0.1
Trip 1	3755.2	4172.4	4694.0	5364.6	6258.6	7510.4	9388.0	12517.3	18775.9	37551.9
Trip 2	2002.1	2224.6	2502.6	2860.2	3336.9	4004.2	5005.3	6673.7	10010.6	20021.1
Trip 3	4130.8	4589.8	5163.6	5901.2	6884.7	8261.7	10327.1	13769.5	20654.2	41308.4
Trip 4	3637.5	4041.6	4546.8	5196.4	6062.4	7274.9	9093.6	12124.9	18187.3	36374.6
Trip 5	3535.2	3928.0	4419.0	5050.3	5892.0	7070.4	8838.0	11784.0	17676.0	35351.9
Survey Mean	**3412.2**	**3791.3**	**4265.2**	**4874.5**	**5686.9**	**6824.3**	**8530.4**	**11373.9**	**17060.8**	**34121.6**

The exploitable biomass of winter flounder (mt) that was estimated to be present in the study area during each month of the survey was compared to the spawning stock biomass of the entire SNE/MA winter flounder stock, which was last assessed in 2008. The spawning stock biomass of winter flounder in the SNE/MA stock in 2007 was estimated to be 3,368mt (NEFSC, 2008). Estimates of the exploitable biomass of winter flounder biomass were calculated using both the doorspread and the wingspread to calculate area swept. Table 15 depicts the estimates of exploitable winter flounder biomass in the study area, using doorspread to calculate area swept. A range of catchability coefficients were used to derive the biomass estimates.

Table 15. Estimates of exploitable biomass in the survey area, using a range of values to represent catchability. Biomass estimates were derived using the doorspread to calculate area swept.

	q=1.0		q=0.8		q=0.6		q=0.4	
	Biomass (mt)	% of SNE/MA biomass	Biomass (mt)	% of SNE/MA biomass	Biomass (mt)	% of SNE/MA biomass	Biomass (mt)	% of SNE/MA biomass
Trip 1	2086.0	61.9%	2607.5	77.4%	3476.6	103.2%	5215.0	154.8%
Trip 2	1084.8	32.2%	1356.0	40.3%	1808.0	53.7%	2712.1	80.5%
Trip 3	2398.3	71.2%	2997.9	89.0%	3997.1	118.7%	5995.7	178.0%
Trip 4	2010.6	59.7%	2513.2	74.6%	3351.0	99.5%	5026.5	149.2%
Trip 5	1909.9	56.7%	2387.4	70.9%	3183.2	94.5%	4774.8	141.8%
Survey Mean	**1897.9**	**56.4%**	**2372.4**	**70.4%**	**3163.2**	**93.9%**	**4744.8**	**140.9%**

Table 16 depicts the estimates of exploitable biomass present in the study area, using the wingspread to calculate area swept. A range of catchability values were used to calculate the biomass estimates. The results show that using a conservative catchability of 1 (100% efficiency of the survey net) yields an exploitable biomass estimate of 3412.2 mt, which is greater than the total spawning stock biomass that was estimated to be present in the SNE/MA stock area in 2007 (3,368mt; NEFSC, 2008). As the assumed catchability coefficient is decreased, the estimates of exploitable biomass increase substantially.

Table 16. Estimates of exploitable biomass in the survey area, using a range of values to represent catchability. Biomass estimates were derived using the wingspread to calculate area swept.

	q=1.0		q=0.8		q=0.6		q=0.4	
	Biomass (mt)	% of SNE/MA biomass	Biomass (mt)	% of SNE/MA biomass	Biomass (mt)	% of SNE/MA biomass	Biomass (mt)	% of SNE/MA biomass
Trip 1	3755.2	111.5%	4694.0	139.4%	6258.6	185.8%	9388.0	278.7%
Trip 2	2002.1	59.4%	2502.6	74.3%	3336.9	99.1%	5005.3	148.6%
Trip 3	4130.8	122.6%	5163.6	153.3%	6884.7	204.4%	10327.1	306.6%
Trip 4	3637.5	108.0%	4546.8	135.0%	6062.4	180.0%	9093.6	270.0%
Trip 5	3535.2	105.0%	4419.0	131.2%	5892.0	174.9%	8838.0	262.4%
Survey Mean	**3412.2**	**101.3%**	**4265.2**	**126.6%**	**5686.9**	**168.9%**	**8530.4**	**253.3%**

Length Frequency

The length frequency of winter flounder that were captured during survey tows was examined to provide better information on the size structure of winter flounder present in the Great South Channel. The observed length frequency of winter flounder captured during each survey trip is shown below in Table 17, and is also shown in Figure 12.

The length frequency of winter flounder captured during the industry-based survey was compared to the length frequency of winter flounder captured in survey strata 1250 and 3550 on the R/V Albatross during the NEFSC spring and fall surveys between 2000 and 2009. The length frequency distributions observed during each survey are shown in Figure 13. The NEFSC survey caught a larger size range winter flounder (5-60 cm) than the industry-based survey (16-54 cm). The results of the Kolmogorov-Smirnov test ($p < 0.001$) indicated that there was a significant difference in the size structure of winter flounder captured by the two surveys.

Larger winter flounder were present in the deeper stations of the study site (Figure 14). The length frequency distributions observed during shallow (< 52 meters) and deep water (> 52 meters) tows were found to be significantly different using a Kolmogorov-Smirnov test ($p<0.001$). The results confirmed the fishermen's hypothesis that larger winter flounder are present in the deeper waters of the Great South Channel.

Table 17. Length frequency distribution of winter flounder observed during each trip of the industry-based survey.

	Trip 1		Trip 2		Trip 3		Trip 4		Trip 5	
Length	# caught	Relative Proportion	# caught	Relative Proportion	# caught	Relative Proportion	# caught	Relative Proportion	# caught	Relative Proportion
16	1	0.02%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
17	2	0.04%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
18	2	0.04%	1	0.03%	0	0.00%	0	0.00%	1	0.06%
19	4	0.08%	1	0.03%	0	0.00%	0	0.00%	1	0.06%
20	10	0.21%	3	0.10%	1	0.02%	2	0.08%	4	0.24%
21	18	0.37%	8	0.27%	3	0.06%	0	0.00%	2	0.12%
22	20	0.41%	19	0.65%	3	0.06%	3	0.11%	6	0.36%
23	35	0.73%	33	1.13%	11	0.21%	5	0.19%	6	0.36%
24	59	1.22%	49	1.68%	22	0.42%	24	0.91%	12	0.72%
25	71	1.47%	62	2.13%	59	1.13%	62	2.36%	27	1.61%
26	121	2.51%	82	2.82%	78	1.49%	127	4.84%	47	2.81%
27	206	4.27%	111	3.81%	124	2.37%	161	6.14%	66	3.95%
28	217	4.50%	138	4.74%	171	3.26%	140	5.34%	74	4.42%
29	236	4.90%	162	5.57%	191	3.64%	147	5.60%	66	3.95%
30	361	7.49%	265	9.10%	263	5.02%	136	5.18%	91	5.44%
31	443	9.19%	317	10.89%	375	7.15%	167	6.36%	115	6.87%
32	588	12.20%	308	10.58%	414	7.90%	171	6.52%	135	8.07%
33	463	9.60%	300	10.31%	540	10.30%	192	7.32%	124	7.41%
34	484	10.04%	274	9.41%	516	9.84%	219	8.35%	165	9.86%
35	384	7.97%	228	7.83%	464	8.85%	256	9.76%	147	8.79%
36	275	5.70%	149	5.12%	466	8.89%	200	7.62%	106	6.34%
37	240	4.98%	123	4.23%	417	7.95%	191	7.28%	111	6.63%
38	187	3.88%	80	2.75%	356	6.79%	123	4.69%	80	4.78%
39	119	2.47%	67	2.30%	251	4.79%	113	4.31%	82	4.90%
40	90	1.87%	46	1.58%	185	3.53%	74	2.82%	77	4.60%
41	72	1.49%	38	1.31%	132	2.52%	52	1.98%	52	3.11%
42	43	0.89%	20	0.69%	76	1.45%	23	0.88%	30	1.79%
43	31	0.64%	9	0.31%	57	1.09%	14	0.53%	14	0.84%
44	18	0.37%	5	0.17%	23	0.44%	12	0.46%	16	0.96%
45	8	0.17%	5	0.17%	17	0.32%	6	0.23%	7	0.42%
46	5	0.10%	3	0.10%	12	0.23%	1	0.04%	3	0.18%
47	5	0.10%	2	0.07%	5	0.10%	2	0.08%	0	0.00%
48	1	0.02%	0	0.00%	7	0.13%	0	0.00%	5	0.30%
49	0	0.00%	0	0.00%	2	0.04%	1	0.04%	1	0.06%
50	0	0.00%	2	0.07%	0	0.00%	0	0.00%	0	0.00%
51	1	0.02%	1	0.03%	1	0.02%	0	0.00%	0	0.00%
52	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
53	1	0.02%	0	0.00%	1	0.02%	0	0.00%	0	0.00%
54	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Total	**4821**		**2911**		**5243**		**2624**		**1673**	

Tagging

During the industry-based survey, a total of 23,187 winter flounder were measured and tagged, making the industry-based survey one of the largest tagging experiments ever conducted for winter flounder. Aside from Howe and Coates (1975), no tagging studies have been completed for winter flounder in the Great South Channel. Therefore, long-term recaptures from the commercial fishery will be important for learning more about the movements of winter flounder in this region.

Winter flounder captured on both survey tows and during depletion experiments were measured and tagged with individually numbered plastic t-bar anchor tags or Peterson discs. In some instances, fish were tagged with both a t-bar anchor tag and a

Peterson disc tag in an attempt to estimate tag retention. The number of tags released on survey tows is shown below in Table 18.

Table 18. Number of tags released on survey tows during each trip of the industry-based survey.

	# of tags released
Trip 1	4715
Trip 2	2395
Trip 3	4842
Trip 4	2344
Trip 5	2461
Total	**16757**

The greatest number of tags were released on survey tows in August, while the fewest tags were released in September.

As time permitted, winter flounder captured during depletion experiments were tagged with t-bar plastic anchor tags. Depletion experiments were conducted during survey trips four and five. A total of 6,430 winter flounder were tagged during the depletion experiments. The distribution of tags released during the depletion experiments is shown below in Table 19.

Table 19. The number of tags released during depletion experiments on survey trips 4 and 5 of the industry-based survey.

	Survey Trip	
Depletion Experiment	4	5
1	1256	515
2	1884	614
3	866	453
4	381	461
Trip Total	**4387**	**2043**

Tag Recaptures

Only two tagged winter flounder were recaptured during survey tows. The lack of recaptures was unexpected. One flounder was tagged and released in June on the third tow of the survey. This flounder was then recaptured during the following tow. Similarly, a tagged winter flounder was recaptured during a survey tow on trip four, but the flounder had also been released during the previous tow. In both instances, these recaptures could not be used to estimate the population size or survival, since the flounder were released and recaptured within the same secondary sampling event. The low number of recaptures during the survey tows precluded the use of the robust design tagging model. Therefore, we were unable to calculate absolute estimates of winter flounder abundance and survival rates using the tagging data from the industry-based survey.

Sixty tagged winter flounder which were tagged and released during depletion experiment tows were later recaptured on subsequent tows of the same depletion experiment. Eight winter flounder were recaptured during depletion experiments in September. All eight of these flounder had been tagged during the same depletion experiment. Fifty two tagged winter flounder were recaptured during depletion experiments in October. Again, all of the winter flounder which were recaptured had been released during an earlier tow within the same depletion tow experiment.

Despite considerable outreach efforts to alert the fishing industry about the industry-based survey, thus far, only one tagged winter flounder has been recaptured and reported by the commercial fishery. A winter flounder that was tagged on 6/22/2010 was later recaptured on 10/3/2010, in the waters of the Great South Channel. The low number of recaptures from the commercial fishery may be attributed to the lack of effort on winter flounder in the SNE/MA stock area. Under Amendment 16 to the Northeast Multispecies FMP, commercial fishermen are prohibited from retaining any flounder caught in the SNE/MA stock area. Therefore, all winter flounder caught in this region are discarded by commercial fishermen, and it is likely that tagged flounder may be overlooked as the fish are being discarded.

There are several potential reasons why so few tagged winter flounder were recaptured during the survey. The most parsimonious explanation is that there was a large abundance of winter flounder present in the Great South Channel. Although over 23,000 winter flounder were tagged during the survey, these tagged flounder may represent a very small proportion of the population that was present in the region. Similarly, the survey was conducted over a very large geographic area, and the average area sampled by the survey net during each tow represented only 0.0009% of the total study area. In addition, the survey net may have also had a low catchability. Therefore, the probability of recapturing a tagged flounder may have been very low.

Another explanation for the low recapture rate could have been tag shedding. Two holding studies were conducted at SMAST, and tagged winter flounder held in the laboratory displayed a tag retention rate of 100%. The Rhode Island Department of Fish and Wildlife used similar t-bar anchor tags on winter flounder in Narragansett Bay, and observed high recapture rates for tagged individuals (12.9%; Powell, 1989). Therefore, a high level of tag shedding appears to be an unlikely explanation for the low number of recaptures. However, the one fish recaptured from the commercial fishery had shed one of the two tags. Another explanation for the low recapture rates is possible emigration of tagged fish from the study area. However, given the relatively sedentary nature of winter flounder, a large-scale emigration of tagged flounder from the study area seems unreasonable. Finally, the low recapture rate may be due to behavioral changes in the winter flounder following tagging. For example, tagged flounder may bury in the sediment following tagging, making them unavailable to the survey net. While this behavior may explain the lack of recaptures in the short term, the survey was conducted over a fairly long period of time. Therefore, it seems unlikely that tagged flounder would remain buried for months following tagging.

Depletion experiments

Four depletion experiments were completed during each of the survey trips in September and October. The results from the depletion experiments completed during September are shown in Figures 15-18. During the first depletion experiment (Figure 15), which was conducted at night, the catch rates increased continually as additional tows were made. The position of the vessel during each of the six tows completed during the experiment is shown in Figure 19. The tow tracks show that the vessel did not cover the exact same fishing grounds during each tow, which may explain why the catch rates increased as subsequent tows were made. The strong tidal currents in the Great South Channel made it difficult for the captain to maintain the same tow course during each tow.

During the second depletion experiment in September (Figure 16), catch rates declined as additional tows were made. However, catch rates remained high during the last tow of the experiment (11 flounder/minute), suggesting that the area had not been depleted completely. Catch rates during the third depletion experiment conducted in September (Figure 17) were highly variable. Generally, the catch rates declined as additional tows were completed. The best results were observed during the final depletion experiment completed in September (Figure 18). Catch rates decreased steadily as additional tows were made.

The results of the four depletion experiments conducted in October are shown in Figures 20-23. During the first depletion experiment (Figure 20), the catch rates decreased steadily during the first four tows. However, the catch rate increased dramatically during the fifth tow. The increase in catch may be attributed to a change in the tide, which occurred between the fourth and the fifth tow. The fishermen who participated in the survey commented that winter flounder catches in the Great South Channel can vary dramatically depending upon the tide.

Catch rates during the second depletion experiment (Figure 21) were variable, and generally increased as additional survey tows were made. The catch rates observed during the third depletion experiment (Figure 22) were also highly variable, and there was no discernable trend in catch rates during the experiment. The results of the fourth depletion experiment are shown in Figure 23. The catch rates decreased steadily during the first three tows. However, during the fourth tow, the tide changed direction, and the catch rates increased again. Catch rates subsequently declined between the fourth and seventh tows.

Further analysis is needed to better understand the results of these depletion tows. One approach may be to examine the tow tracks for regions of overlap during each of the depletion experiments, as was done for the cooperative monkfish survey conducted by the Northeast Fisheries Science Center (NEFSC, 2010). This will allow the catch rates to be corrected for instances where the tow paths differed between tows made within a single depletion experiment. Further work is also needed to generate estimates of the catchability of the survey net.

Vessel Effect

A vessel effect can exist when multiple vessels are used during a survey even though the same net is utilized, and vessel characteristics are similar. A vessel effect was examined for by testing for differences in tow speed, scope ratio, and net dimensions between vessels. The mean vessel tow speed was generally around three knots, which was consistent with survey protocols. However, there was a significant difference in the mean tow speed between vessels (Figure 24). A ranked ANOVA was used to test for differences in the mean tow speed by vessel after the assumptions of normality and homogeneity of variances were not met (Sokal and Rholf, 2001). Weinberg and Kotwicki (2008) found a significant difference in tow speed among vessels that participated in the eastern Bering Sea survey. There were also significant differences in the scope ratio between vessels, although the vessels followed a similar pattern of the amount of warp set compared to the depth (Figure 25). An analysis of covariance was used to test for differences in the slope between vessels (Sokal and Rholf, 2001). The F/V Iberia II and the F/V United States tended to set more discrete amounts of warp over larger depth ranges than the other vessels. For net dimensions measured, there was a significant difference in the mean value by vessel for headline readings. There was no significant difference in the mean value for the wing or door sensors. A ranked anova was also used to test for differences in the mean value by sensor between vessels after parametric assumptions were not met (Sokal and Rholf, 2001). The degrees of freedom were corrected after testing for serial independence (Sokal and Rholf, 2001). The effective degrees of freedom were calculated following the method described in McIntyre and McKitrick (2009). Trip three had the highest headline height. The distance between the wings was relatively consistent between trips with the exception of trip five, which had a smaller wing spread. The door spread was also relatively similar among trips with slight deviations in the values for trips three and five.

Table 20. Mean value for the headline, wing and door measurements by trip in meters.

Trip	Headline Mean (m)	Wing Mean (m)	Door Mean (m)
1	2.69	13.74	24.21
2	2.67	14.06	24.27
3	3.16	14.45	23.88
4	2.56	N/A	24.11
5	2.69	12.96	23.85

Acknowledgements

We are indebted to the many people whose hard work made it possible to complete this survey. We would like to thank Adam Barkley and Doug Zemeckis, who completed survey trips and helped with data collection. We are grateful to the captains and crews of each vessel that participated in the survey for their hard work under difficult conditions. We are especially grateful to the captains who were willing to share their knowledge about winter flounder with us. Their practical experience was a great asset to the scientists at SMAST. We would also like to thank the members of the SMAST groundfish steering committee for their helpful feedback. Their input was invaluable in designing the survey, and their perspective helped us better understand the results. We would like to thank Reidar's Manufacturing, especially Hans and Tor Bendiksen, for their help in transporting the survey nets to and from each vessel. We thank Vin Malkoski with the Massachusetts Division of Marine Fisheries for giving us a place to store the survey nets in between trips. Janice Plante and Commercial Fisheries News did an excellent job publicizing this project. This survey was generously funded through a grant by the National Oceanic and Atmospheric Administration, and the Massachusetts Marine Fisheries Institute.

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Figures

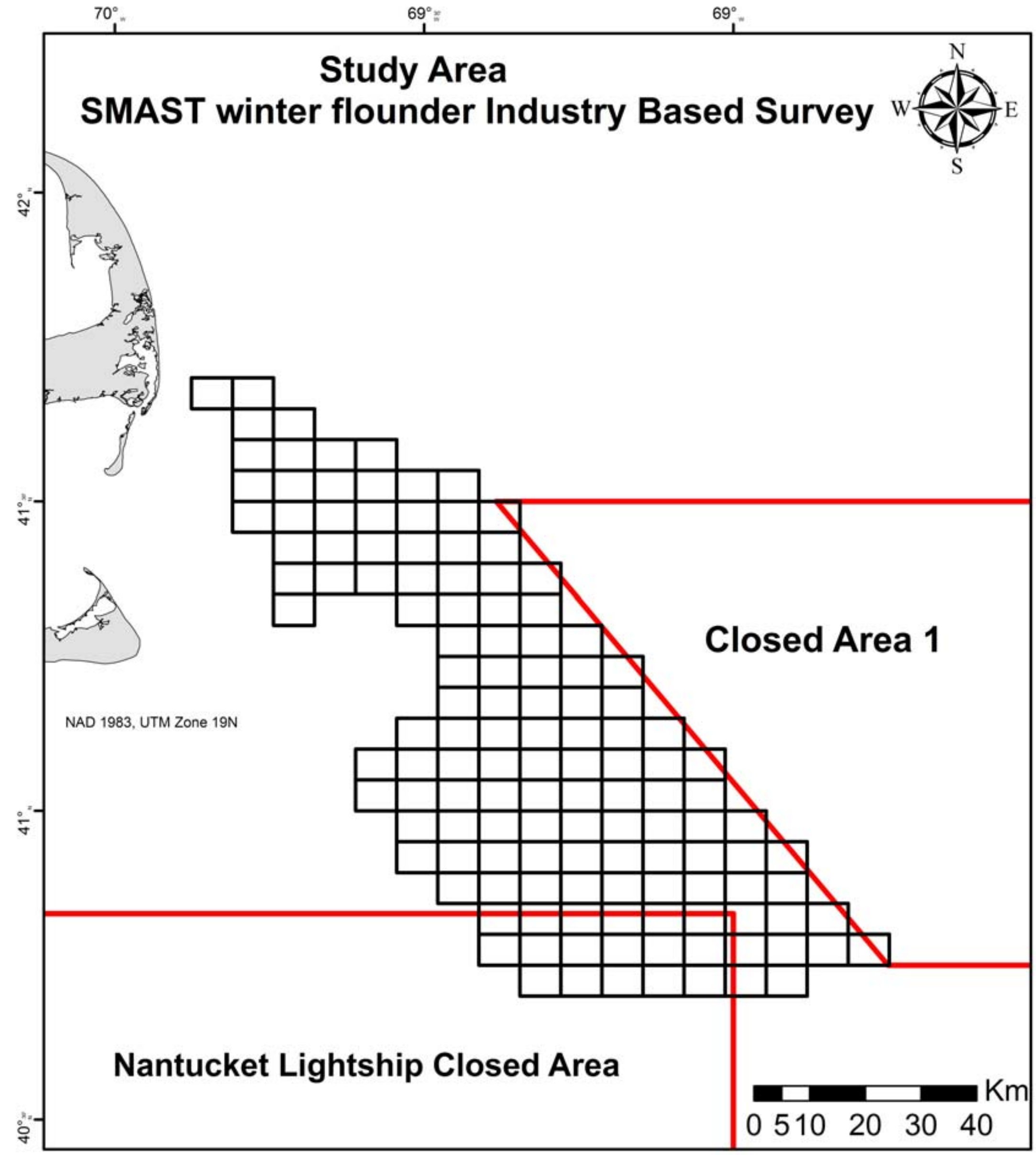

Figure 1. Map of the study site that was sampled during the industry-based survey. The study site was divided into 132 nine square nautical mile grid cells.

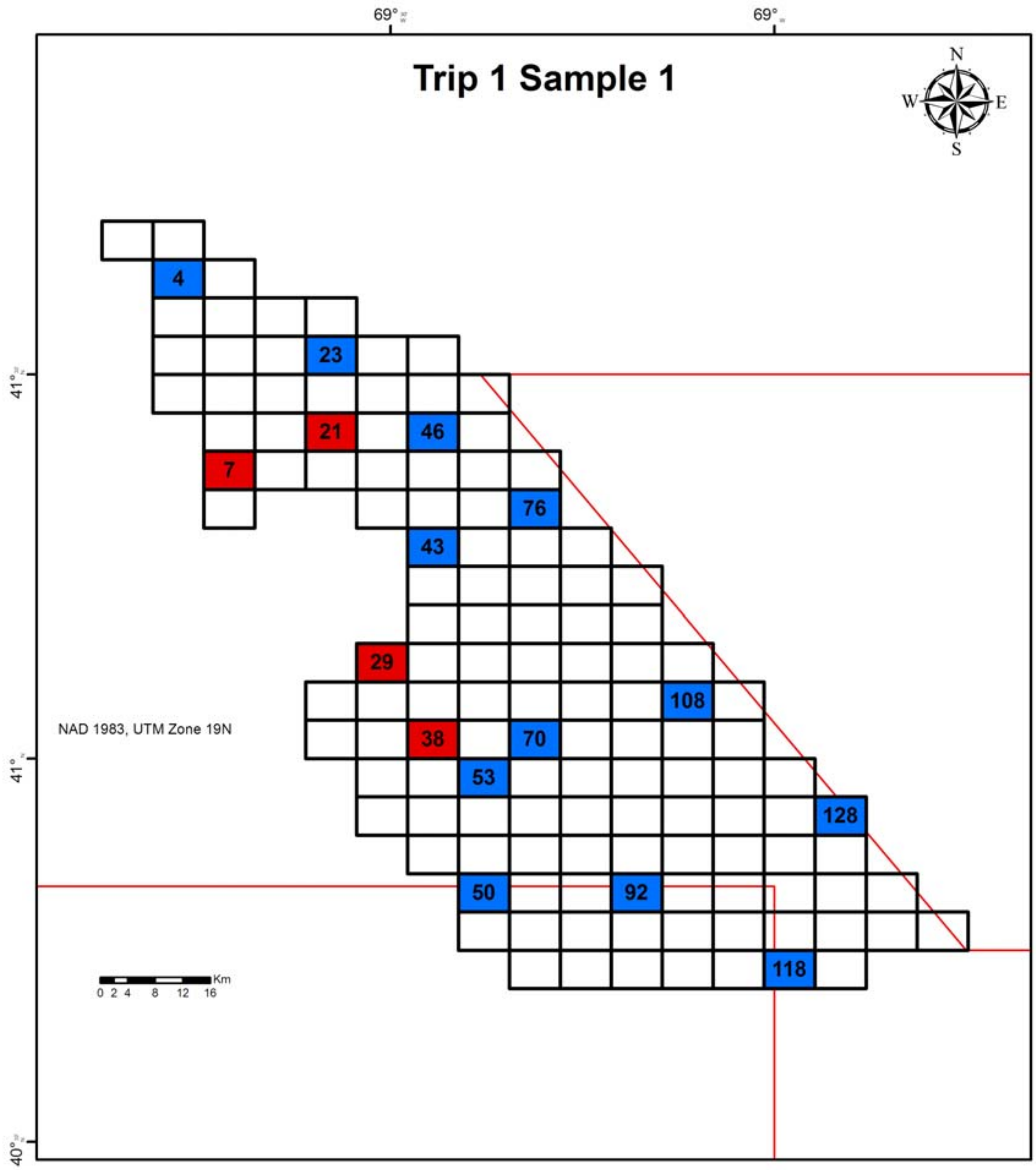

Figure 2. Example of survey tows that were completed during a secondary sampling event. The grid cells selected that were selected at random are shown in blue, and the grid cells selected by the captain are shown in red. The secondary sampling event was conducted by completing a survey tow in each grid cell, in a north to south direction.

Figure 3. Each winter flounder was tagged with two individually numbered plastic t-bar anchor tags. The tags were attached to each flounder in the dorsal musculature.

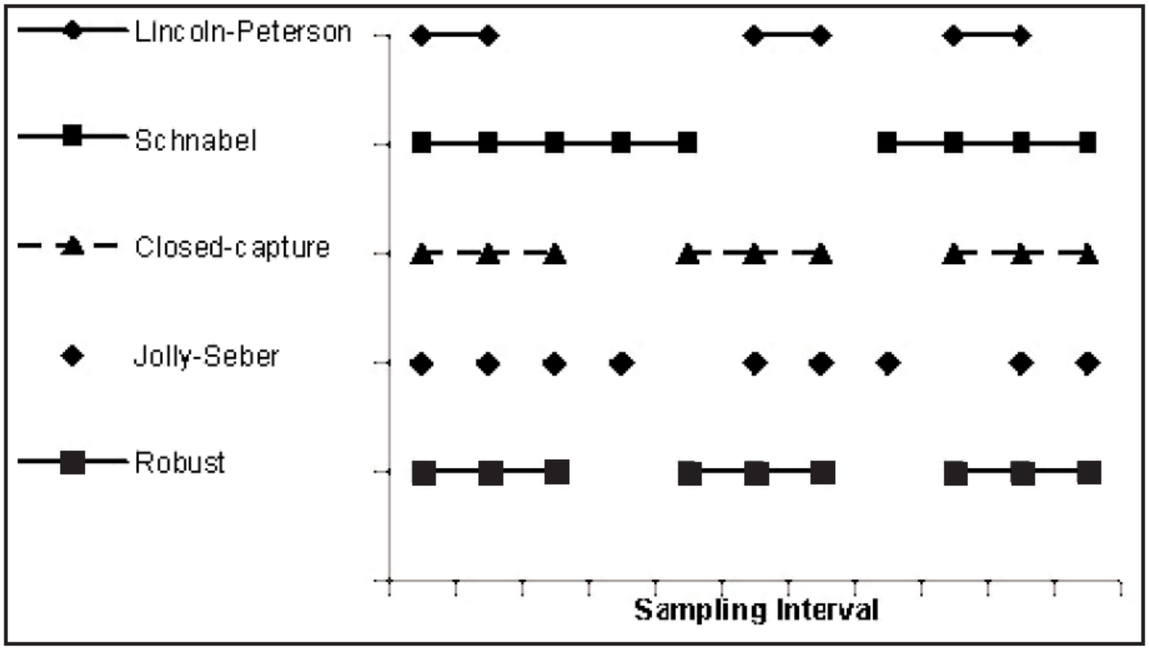

Figure 4. Diagram demonstrating assumptions about capture probabilities for each type of capture-recapture model. Each marker represents a sampling event. The solid lines connecting markers indicate closed populations with equal capture probabilities. Dashed lines between samples indicate closed populations with unequal capture probabilities. Gaps represent intervals where populations are open (from Pine et al. 2003).

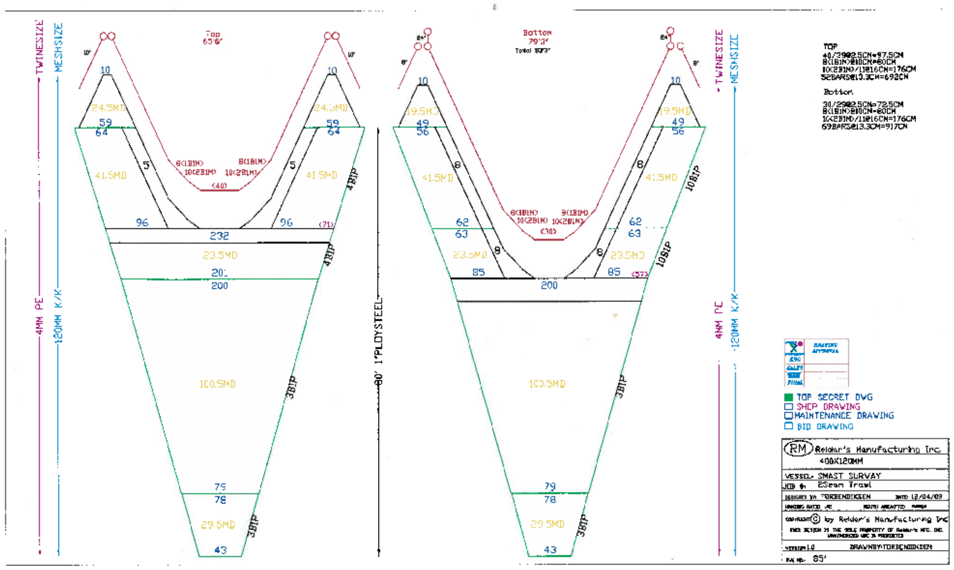

Figure 5. Diagram of the survey nets that were constructed by Reidar's Manufacturing for the industry-based survey in the Great South Channel.

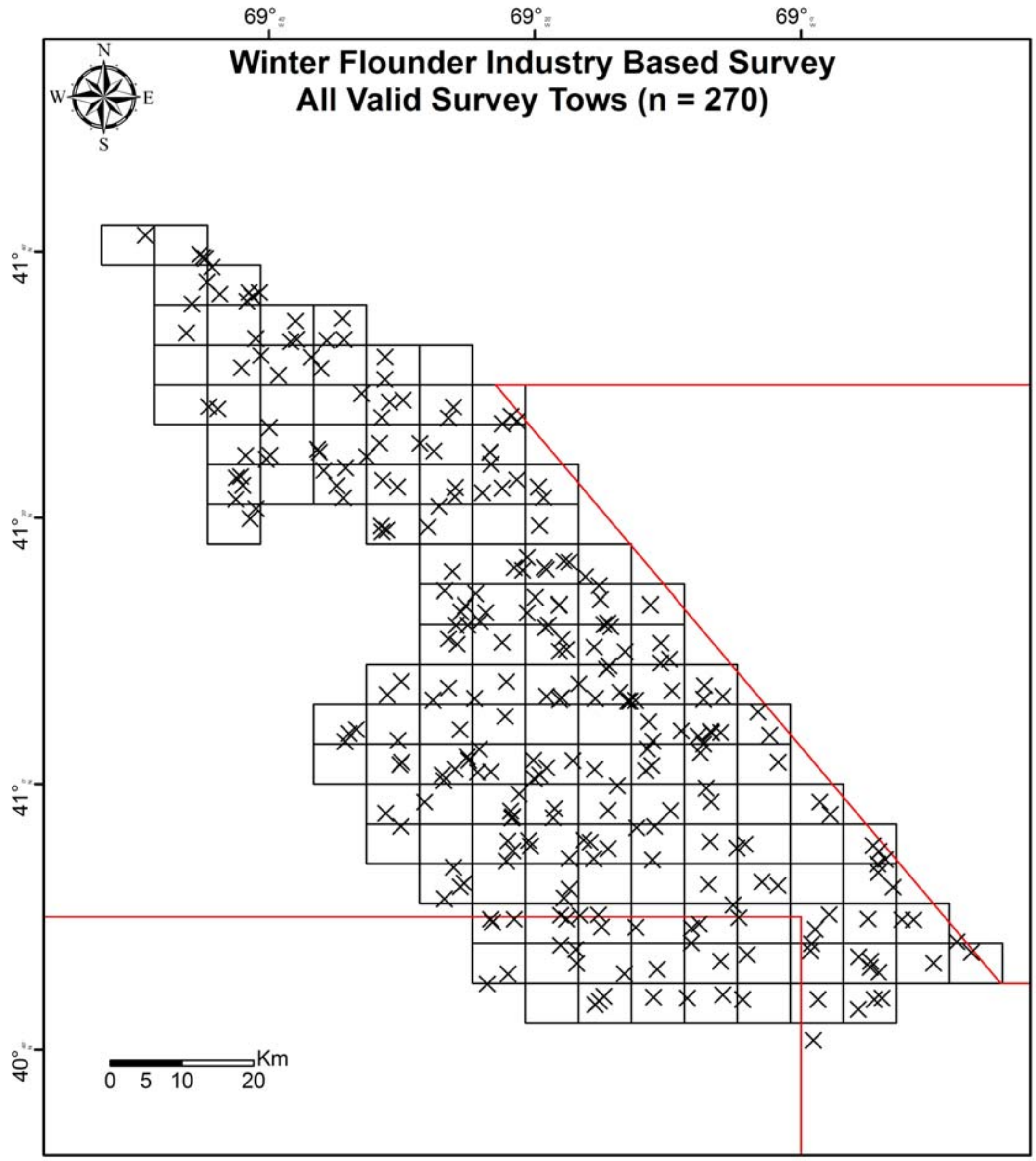

Figure 6. End locations of the 270 valid survey tows that were completed during the industry-based survey for winter flounder in the Great South Channel.

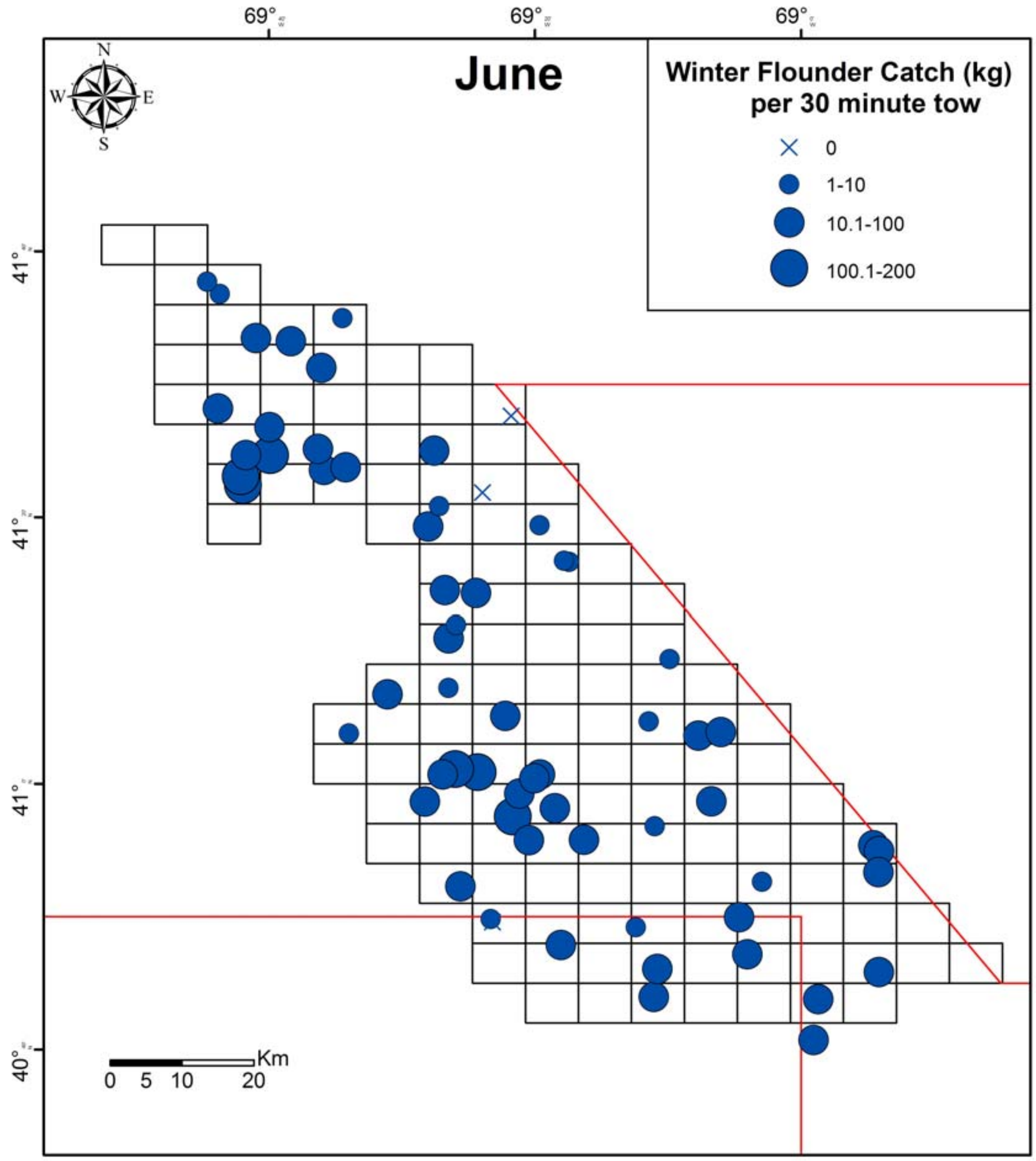

Figure 7. Distribution of standardized winter flounder catches (kg) observed during the month of June.

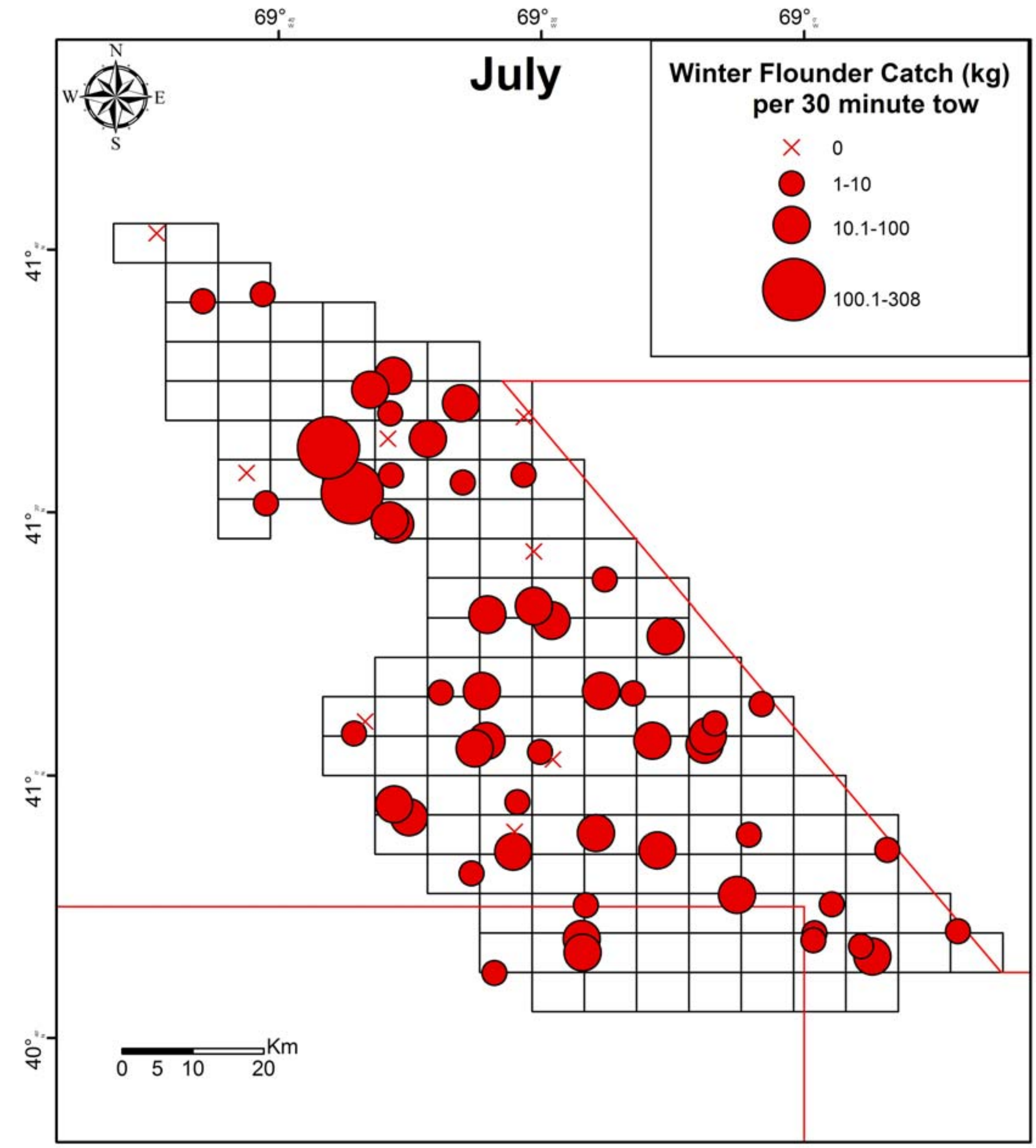

Figure 8. Distribution of standardized winter flounder catches (kg) observed during the month of July.

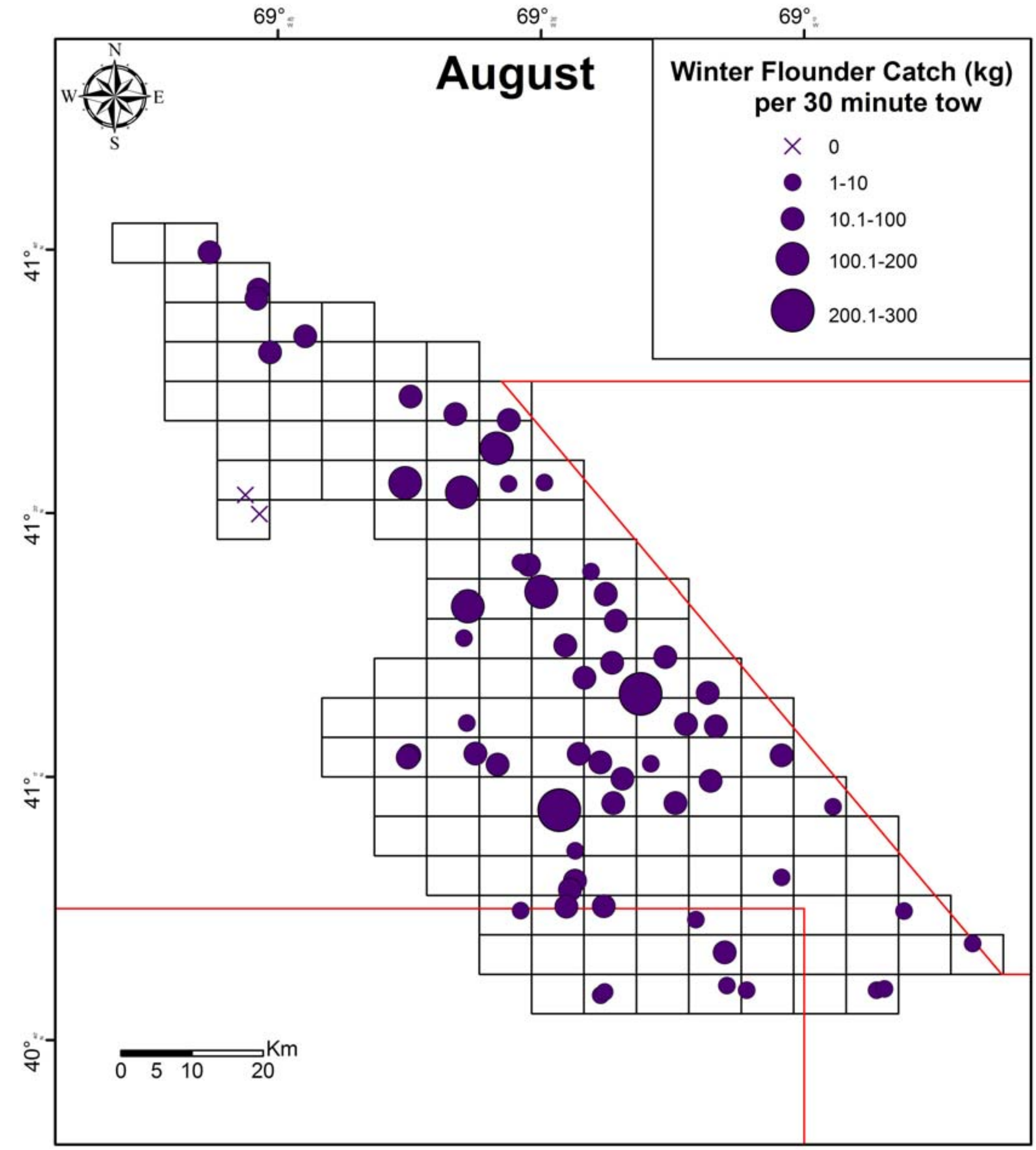

Figure 9. Distribution of standardized winter flounder catches (kg) observed during the month of August.

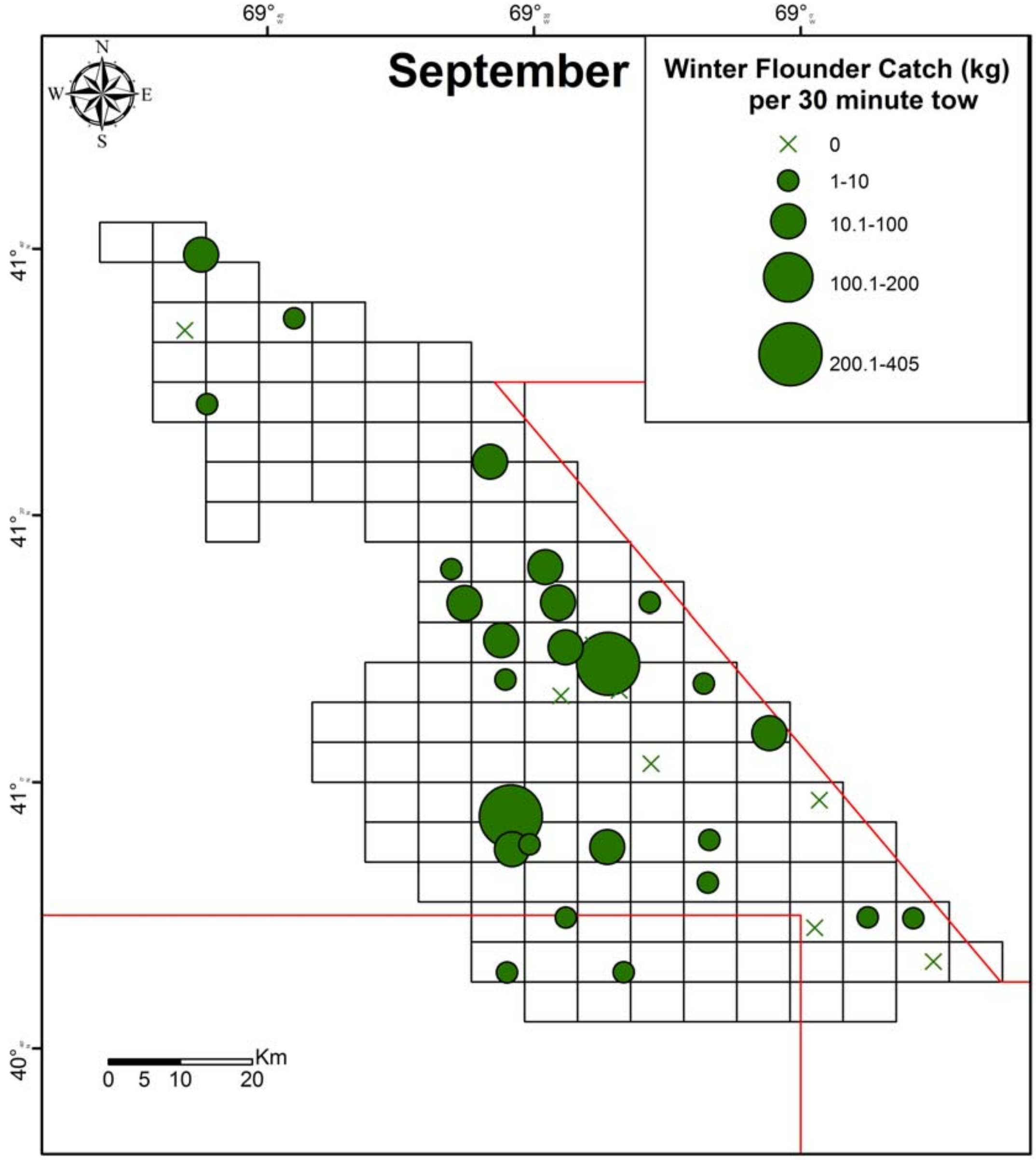

Figure 10. Distribution of standardized winter flounder catches (kg) observed during the month of September.

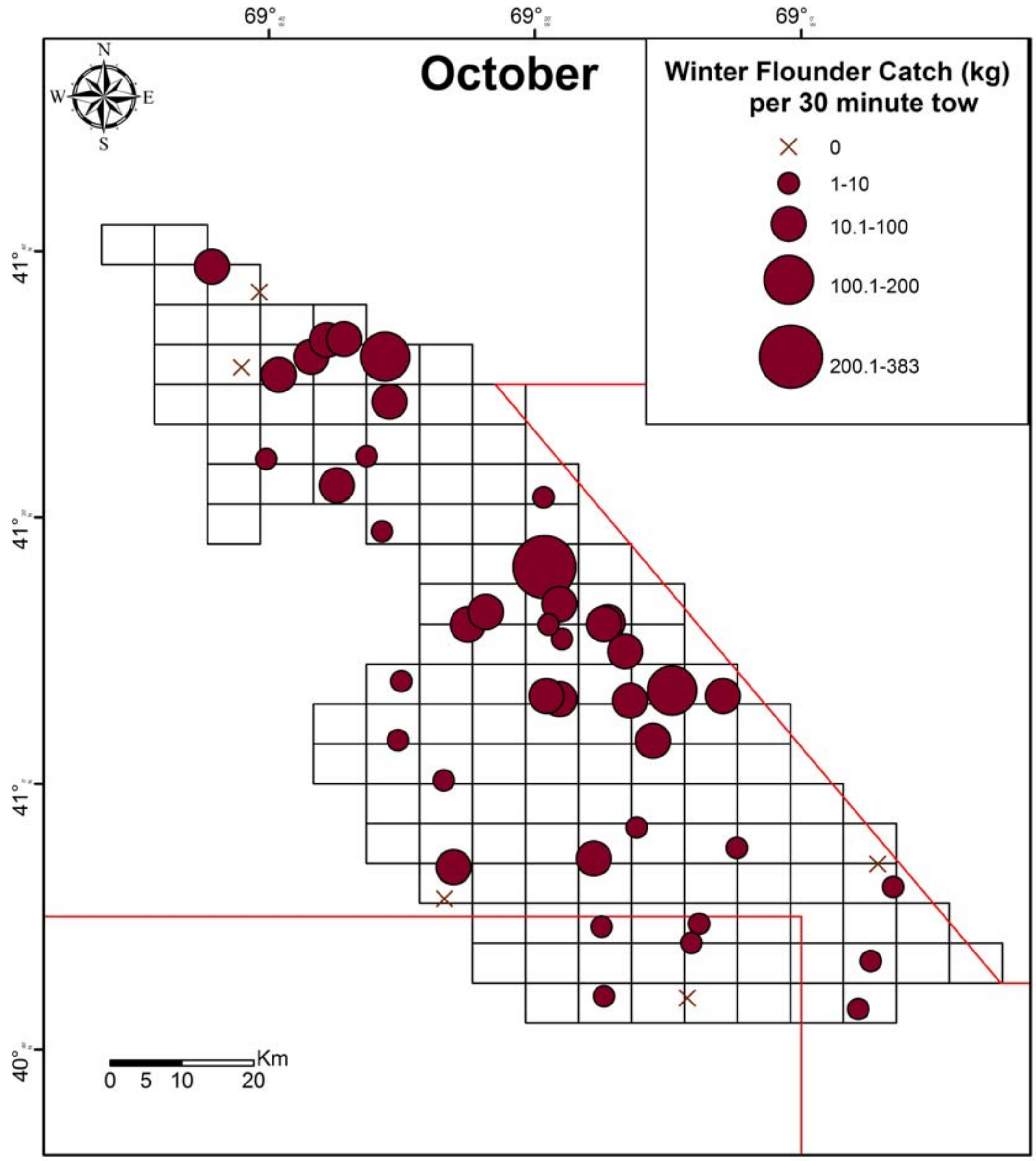

Figure 11. Distribution of standardized winter flounder catches (kg) observed during the month of October.

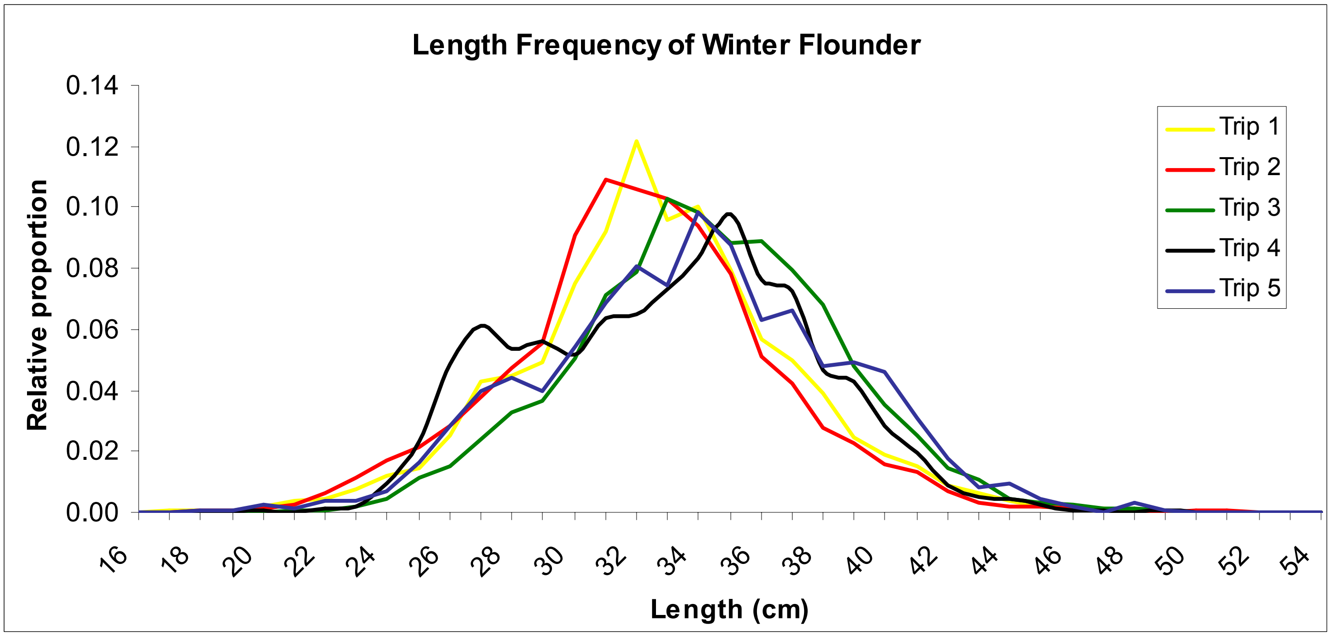

Figure 12. Length frequency of winter flounder observed on survey tows during each trip of the industry-based survey.

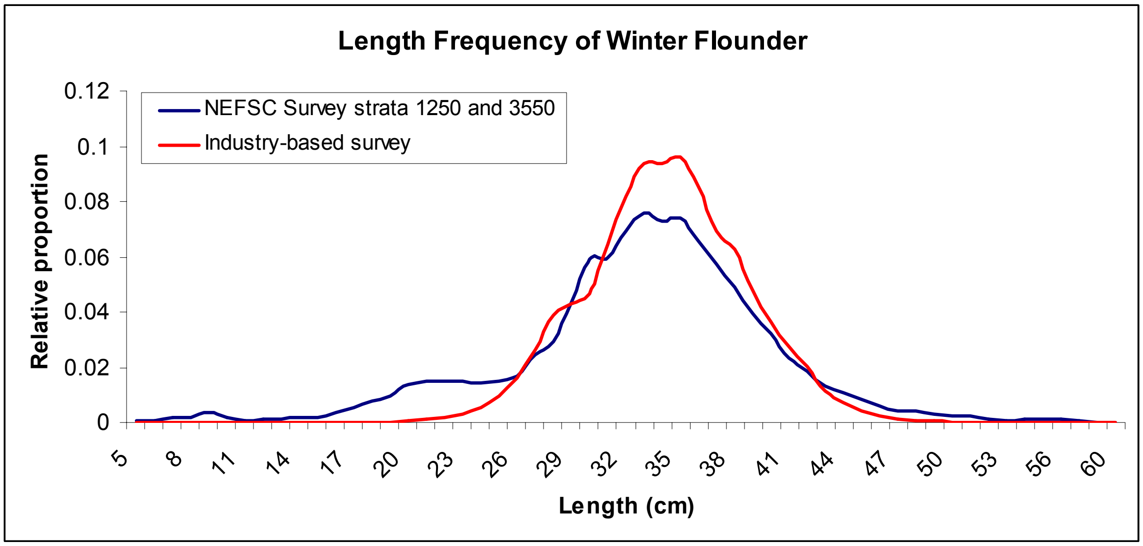

Figure 13. Length frequency distribution of winter flounder observed during the industry-based survey and the NEFSC spring and fall survey strata 1250 and 3550 between 2000 and 2009.

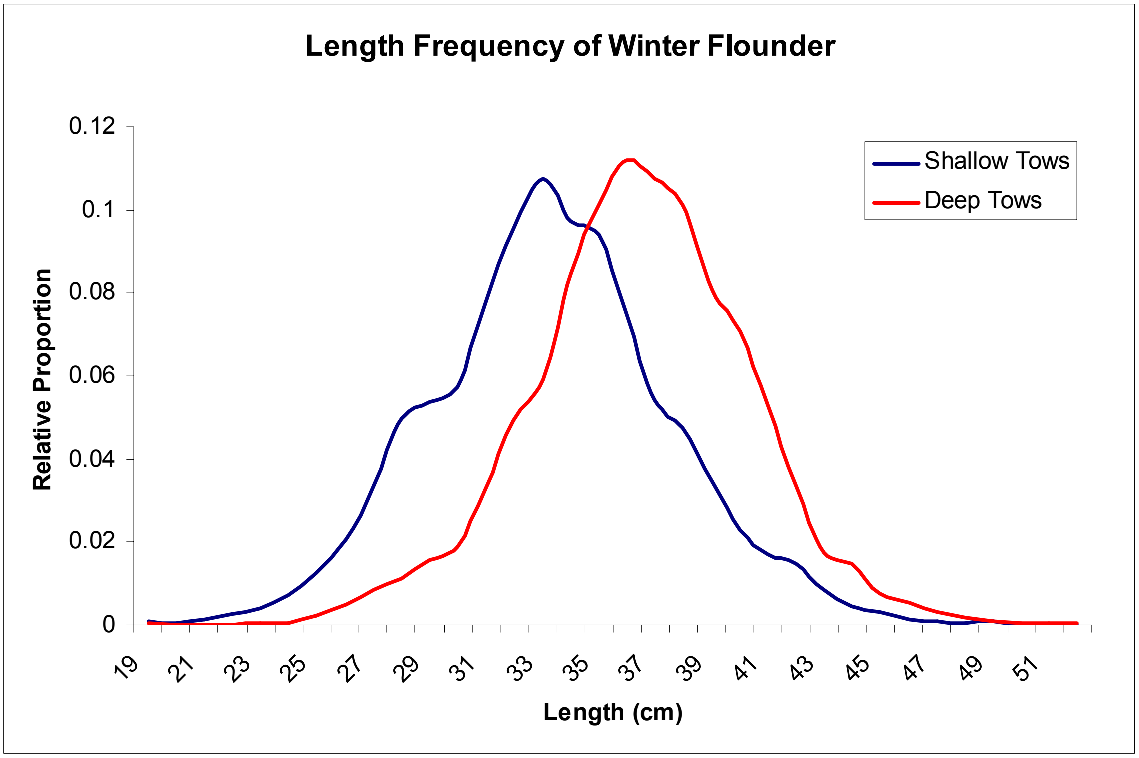

Figure 14. Length frequency of winter flounder caught on shallow (<52 meters) and deep (>52 meters) survey tows during the industry-based survey.

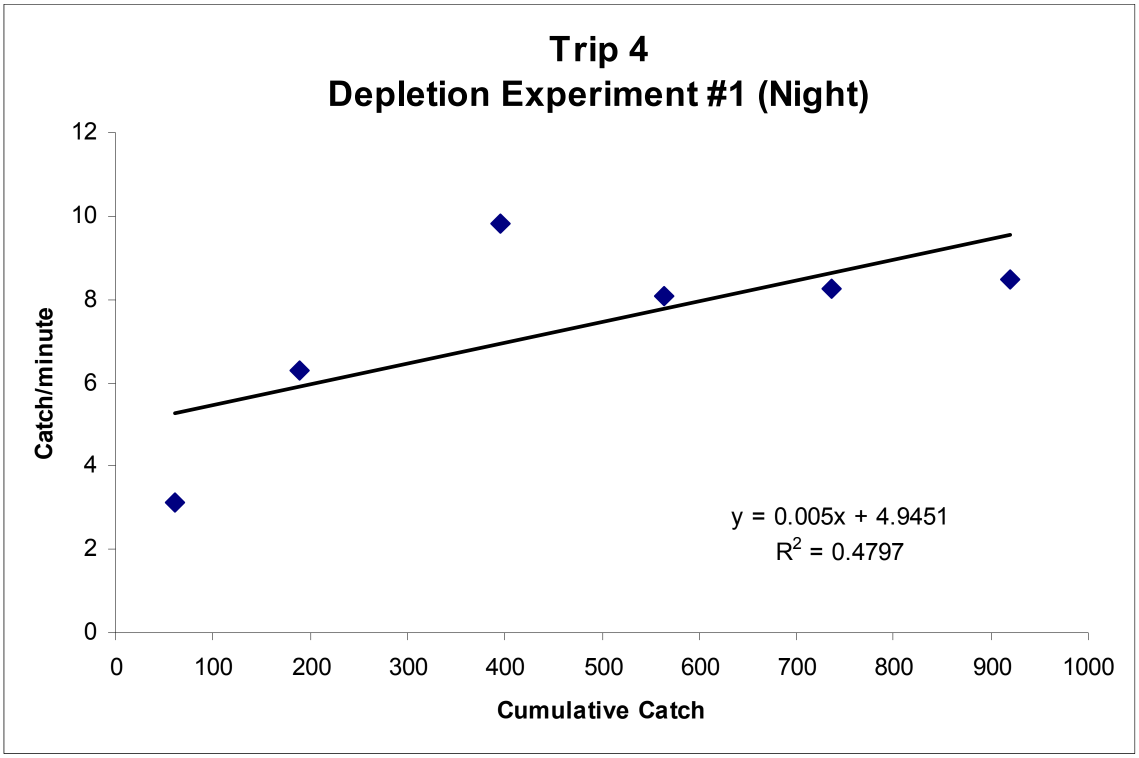

Figure 15. Results from depletion experiment #1 conducted in September.

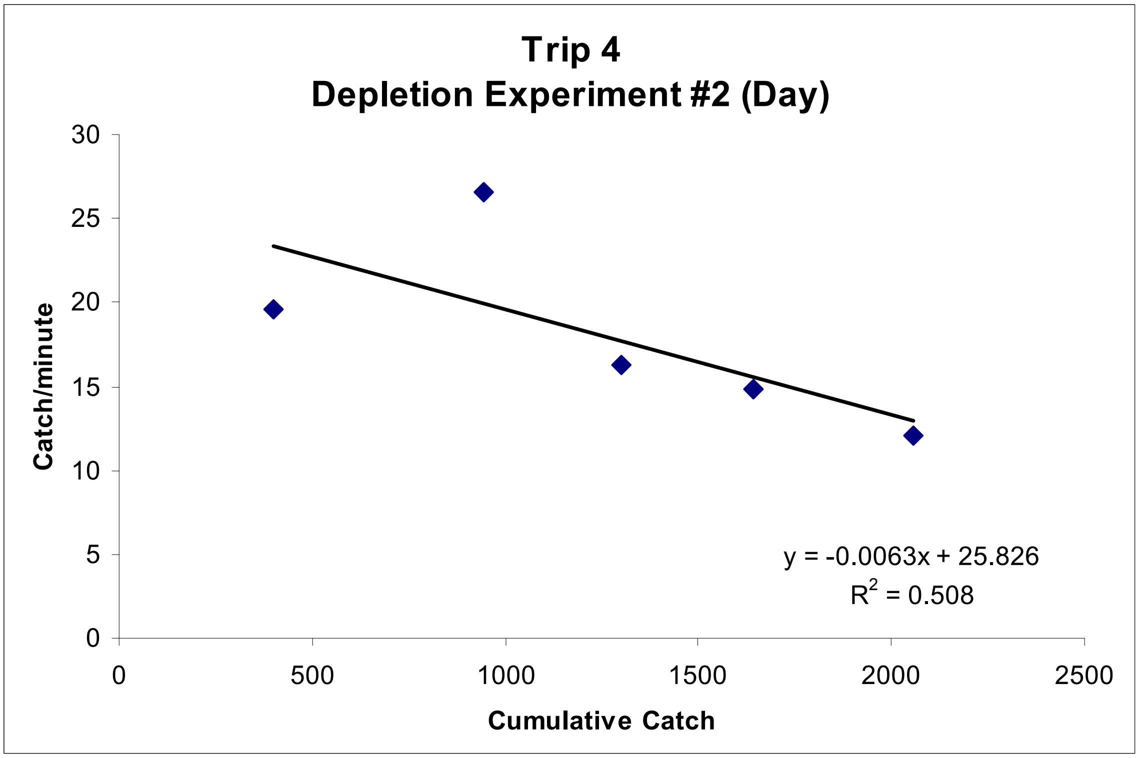

Figure 16. Results from depletion experiment #2 conducted in September.

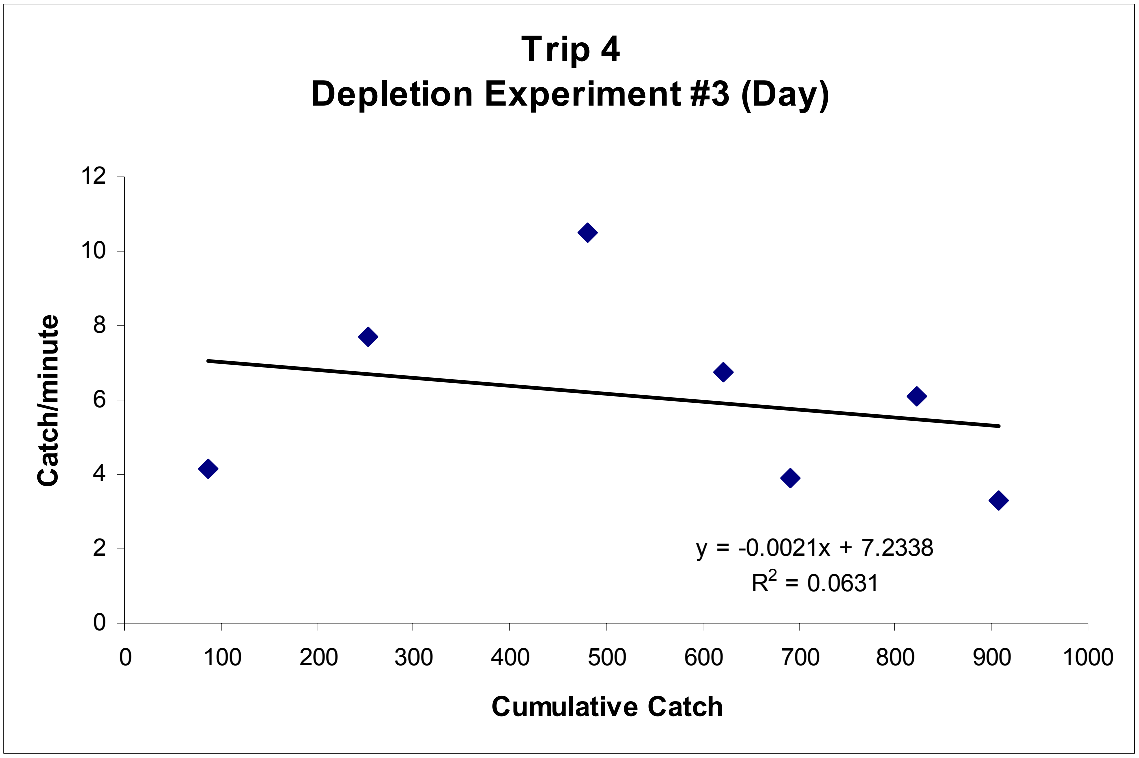

Figure 17. Results from depletion experiment #3 conducted in September.

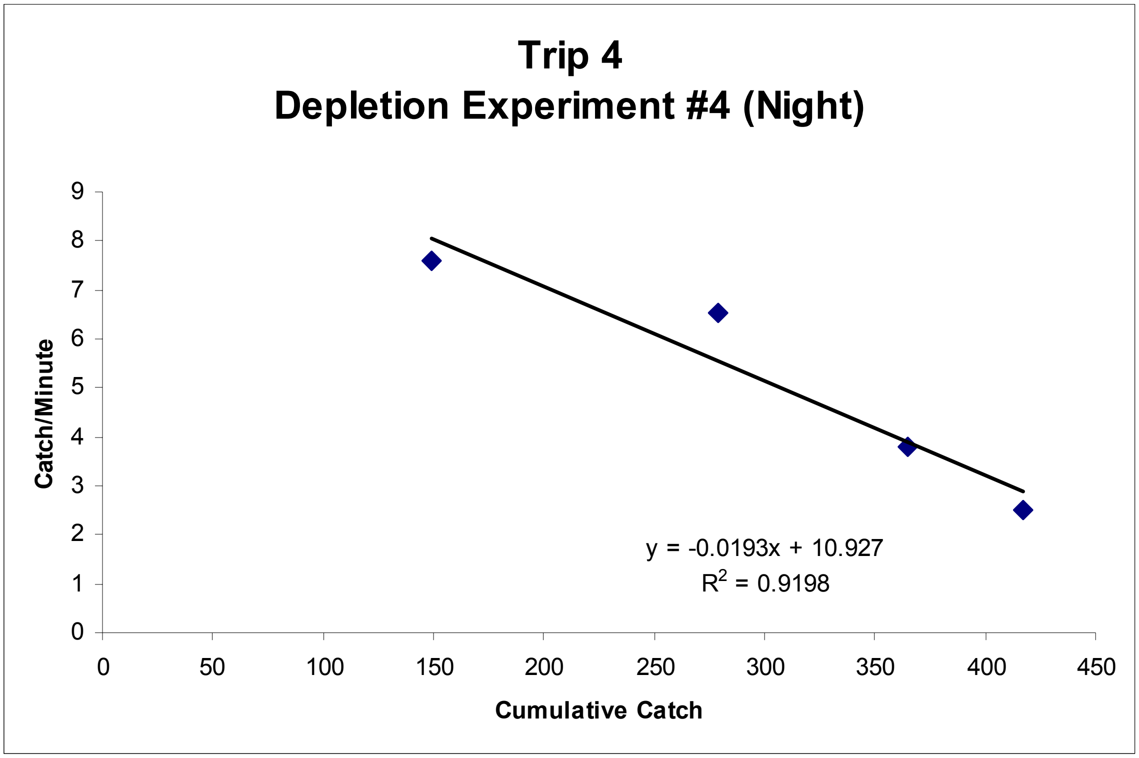

Figure 18. Results from depletion experiment #4 conducted in September.

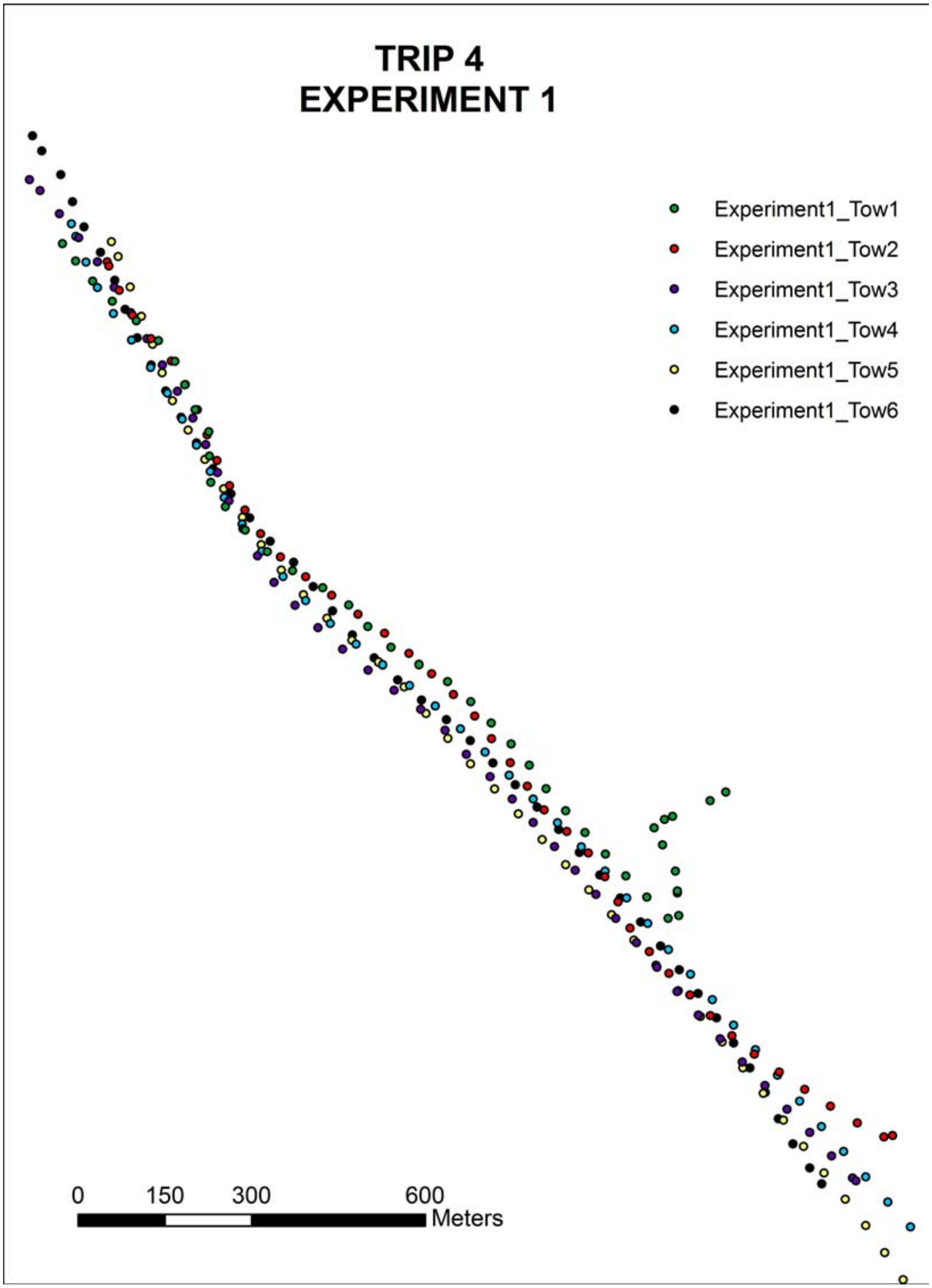

Figure 19. Position of the vessel during each of the tows made during depletion experiment #1 in September. The position of the vessel was recorded every 30 seconds during the tow.

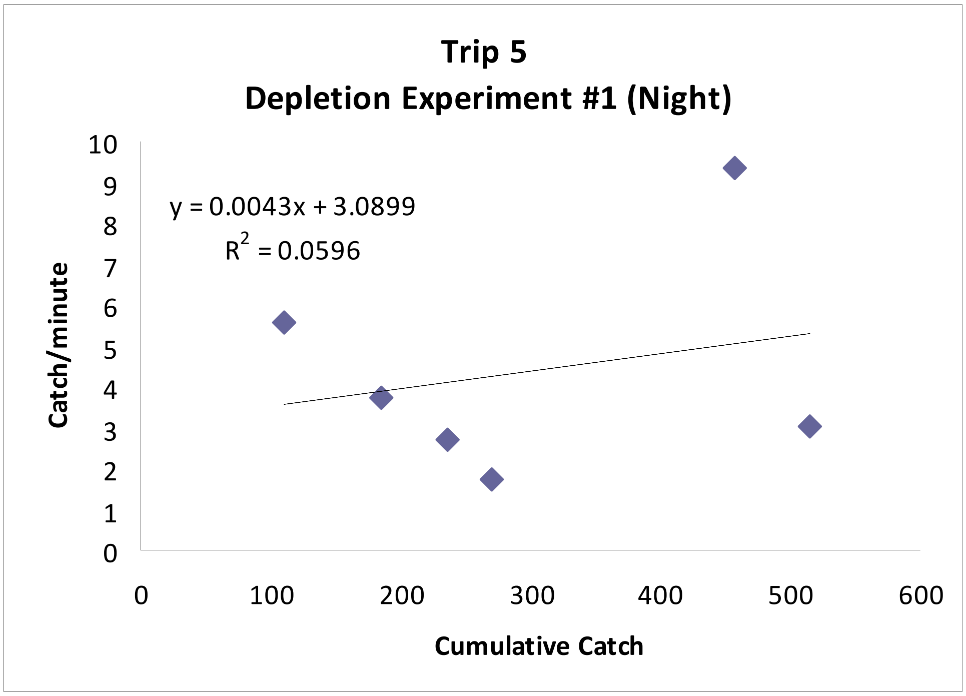

Figure 20. Results from depletion experiment #1 completed in October.

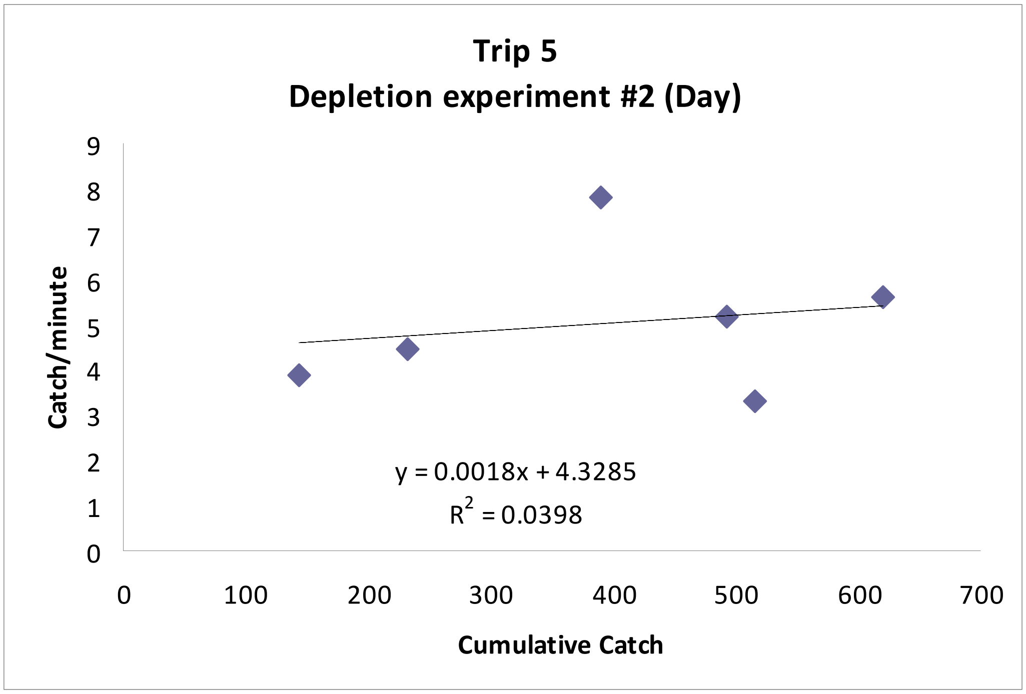

Figure 21. Results from depletion experiment #2 completed in October.

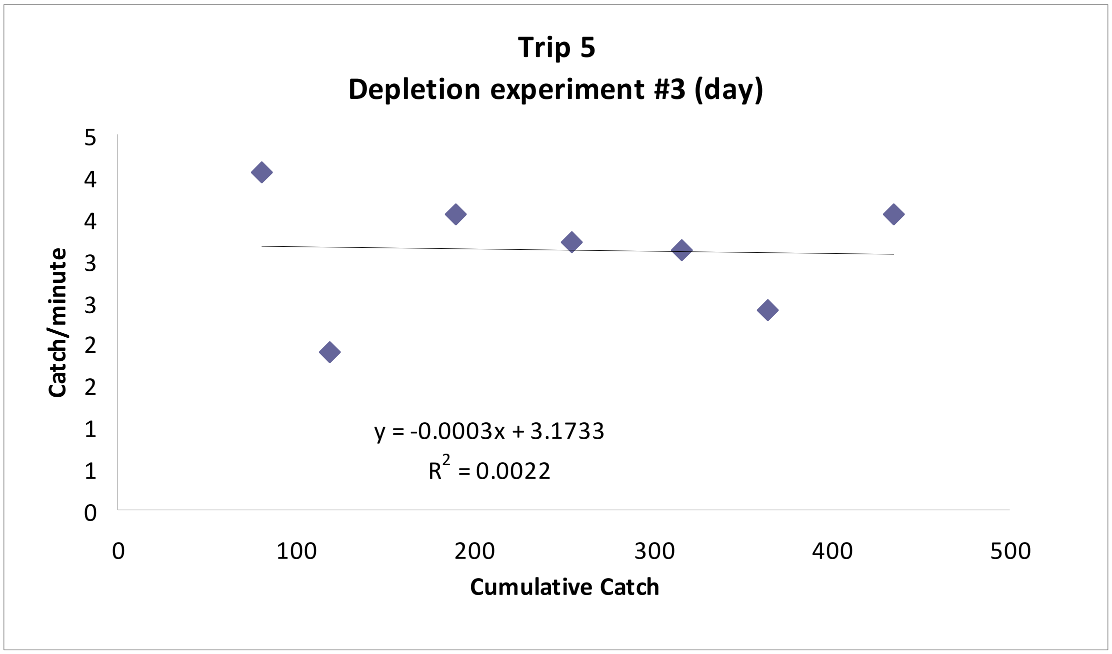

Figure 22. Results from depletion experiment #3 completed in October.

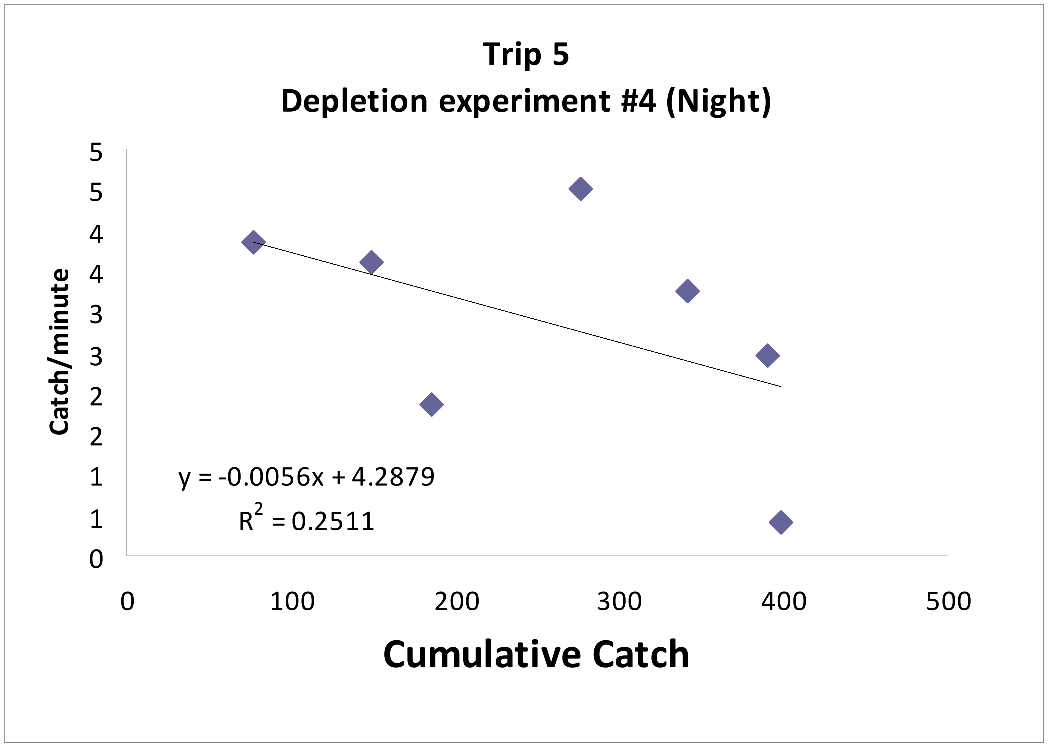

Figure 23. Results from depletion experiment #4 completed in October.

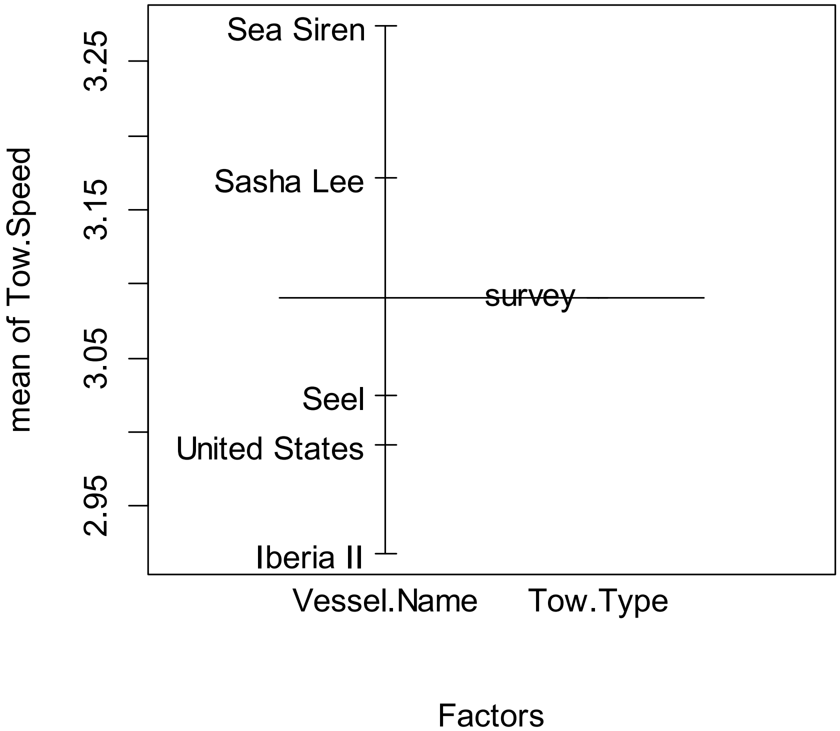

Figure 24. Plot of mean tow speed in knots by vessel for survey tows for the winter flounder industry-based survey.

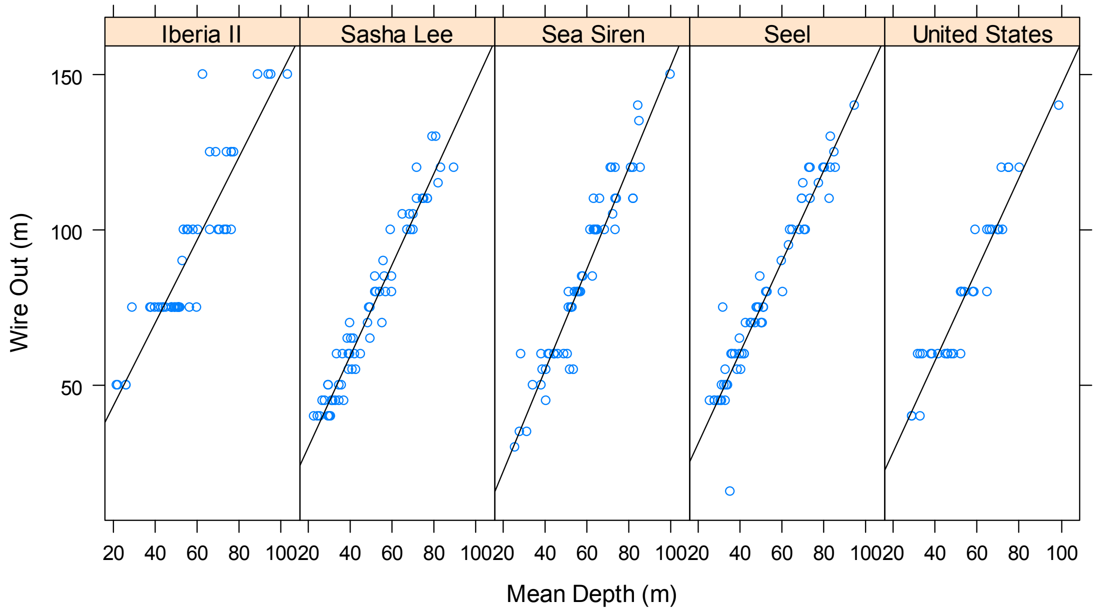

Figure 25. Plot of wire out (meters) against mean depth (meters) by vessel for the winter flounder industry-based survey.

SDWG Background WP#11
May 2011
TOR1-discard rate estimates

A Working Paper in support of SARC 52 Winter Flounder TOR 1:“Estimate catch from all sources including landings and discards. Characterize the uncertainty in these sources of data.”

A Comparison of Discard Rates Derived from At-Sea Monitoring and Observer Trips

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April 2011

Introduction

- The Northeast Fishery Observer Program (NEFOP; NEFOP 2010a; NEFOP 2010b) implemented a new data collection program called At-Sea Monitoring (ASM; NEFOP 2010c) on May 1, 2010.
- This sampling program was required by Amendment 16 to Northeast Multispecies Fishery Management Plan (FMP) for compliance monitoring of NE groundfish trips in fishing year 2010.
- ASM sampling program uses similar sampling protocols as the observer program (slightly less biological sampling – no age structure
- Deployment of monitors and observers are through the Pre-Trip Notification System (PTNS; Palmer et al. In-prep).
- Coverage of New England groundfish fleets, trips using gear that target groundfish include: longline, handline, longline, otter trawl, and gillnet. The otter trawl includes three types of trawl: bottom trawl for fish, Ruhle trawl and haddock separator trawl.
- Funding available to provide approximately 30% coverage of NE groundfish trips with ASM and 8% coverage with Observer.
- Useful to know if the two programs are sampling the same population of groundfish trips before pooling these data together for discard estimation of various species.
- This report summarizes the number of trips and compares the discard rates using the first 10 months of data collection May 1, 2010 to December 31, 2010) by NEFOP ASM and observers (OB).

Methods

- NEFOP data from May through December
- Partitioned data into two sets based on program codes
    - ASM included program codes: 230, 231, 232, 233, and 234
    - OB included program codes: 000, 010, 130, 146, 147, and 150
    - Weight was converted to live pounds
    - Only observed hauls used
    - Each dataset was stratified by calendar quarter and 7 gear/mesh: Longline, Handline, Otter trawl, Ruhle trawl, Haddock Separator trawl, Gillnet (large; extra-large);
- To identify groundfish trips, used the *link1* in the Oracle table used for Quota-Monitor of Sector's annual catch entitlements.
- Summarized trips by dataset and calendar quarter to identify temporal coverage patterns

- Summarized trips by dataset and statistical area and three regions (Gulf of Maine statistical areas 511-515; Georges Bank statistical areas 521-526, 561-562; and Southern England statistical areas 537-539, 611-639)
- Derived discard rates and associated variance for 18 species (8 species with multiple stock components) and all species combined using Equations 1 and 2;
    - Species include: American plaice, Atlantic cod, Atlantic halibut, Atlantic wolffish, haddock, ocean pout, pollock, redfish, white hake, windowpane flounder, winter flounder, witch flounder, yellowtail flounder, monkfish, fluke, silver hake, red hake, and scallops
- Calculated the difference between dataset discard rate and the variance of the difference between discard rate using Equations 3 and 4

Eq 1.
$$\hat{R}_{jh} = \frac{\sum_{i=1}^{n_h} d_{ijh}}{\sum_{i=1}^{n_h} k_{ih}}$$

Eq 2.
$$V\left(\hat{R}_{jh}\right) = \frac{1}{n_h \bar{k}_h^2}\left[\frac{\left(\sum_{i=1}^{n_h} d_{ijh}^2\right) + \hat{R}_{jh}^2\left(\sum_{i=1}^{n_h} k_{ih}^2\right) - 2\hat{R}_{jh}\left(\sum_{i=1}^{n_h} d_{ijh} k_{ih}\right)}{(n_h - 1)}\right]$$

Eq 3.
$$\hat{R}_{diff} = \hat{R}_{jhASM} - \hat{R}_{jhOB}$$

Eq. 4
$$V(\hat{R}_{diff}) = V(\hat{R}_{jhASM}) + V(\hat{R}_{jhOB})$$

where,
R_{jh} is the discard rate of stock j in stratum h;
d_{ijh} is the discard weight of the stock j within trip i in stratum h;
k_{ih} is the kept weight of all species within trip i in stratum h;
n_h is the number of observed trips in stratum h;
k_h bar is the mean kept of all species within the stratum;
Rdiff is the difference between ASM and OB discard rates for stock j in stratum h;
Stratum h represents gear/mesh and calendar quarter;

- 95% confidential intervals were derived for each difference between discard rates (cell)
- Cells were excluded from analysis if sample size (number of trips) in either dataset was equal to 1
- Difference between discard rates were compared against zero

Results

- There were 513 OB groundfish trips and 2,171 ASM groundfish trips during the May through December 2010 period (Table 1).
- Percentage of groundfish trips by dataset and calendar quarter reveals some temporal variability (Figure 1).
- ASM and OB sea days used and groundfish trip activity, by week, provide insight into quarterly patterns (Figures 2 and 3)
- Percentage of groundfish trips by dataset and statistical area reveals some spatial variability (Figure 4a), but when aggregated by region, less variability is evident (Figure 4b).
- 435 cells (differences between ASM and OB discard rates by species/stock, gear/mesh and calendar quarter) were compared against zero
- 90% of the cells overlapped zero (392 of 435)
- 10% of the cells did not overlap zero (43 of 435)
- Some cells had very small sample sizes
- 21 of the 43 non-overlapping cells had discards < 10 lbs (small quantities of discards)

- Specific to Winter flounder
    - GOM Winter flounder: all 11 cells overlap zero (Figure 5)
    - GB winter flounder: all 9 cells overlap zero (Figure 6)
    - SNE winter flounder: 11 of 12 cells overlap zero (Figure 7)
- Other species/stocks (Figures 9 to 33)

Conclusions

- Expectation: 5% of cells will not overlap zero if there is no statistical difference between the OB and ASM discard rates
- No major differences between discard rates from OB and ASM trips
- Confirms assumption that OB and ASM programs are sampling same population of groundfish trips

Literature

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Table 1. Summary of Northeast Fisheries Observer Program 's program names, program codes, number of groundfish trips and observed hauls, by observer (OB) and at-sea monitoring (ASM) dataset for NEFOP collected from May through December 2010.

Program Name	OB PROGRAM Code	OB DATA		ASM DATA		ASM PROGRAM Code
		Trips	Hauls	Trips	Hauls	
STANDARD SEA SAMPLING TRIPS	000	373	1,595	1,983	7,583	230
TRAINING TRIPS	010	64	249			
US/CANADA MANAGEMENT AREA	130	74	1,684	141	3,016	231
CLOSED AREA I HADDOCK HOOK SAP	146			41	399	233
CLOSED AREA II YELLOWTAIL FLOUNDER/HADDOCK SAP	147	2	59	6	147	234
TOTAL TRIPS		513		2,171		

Figure 1. Percentage of NEFOP trips, by dataset (observer, OB and at-sea monitoring ASM) and calendar quarter for groundfish trips from May through December, 2010.

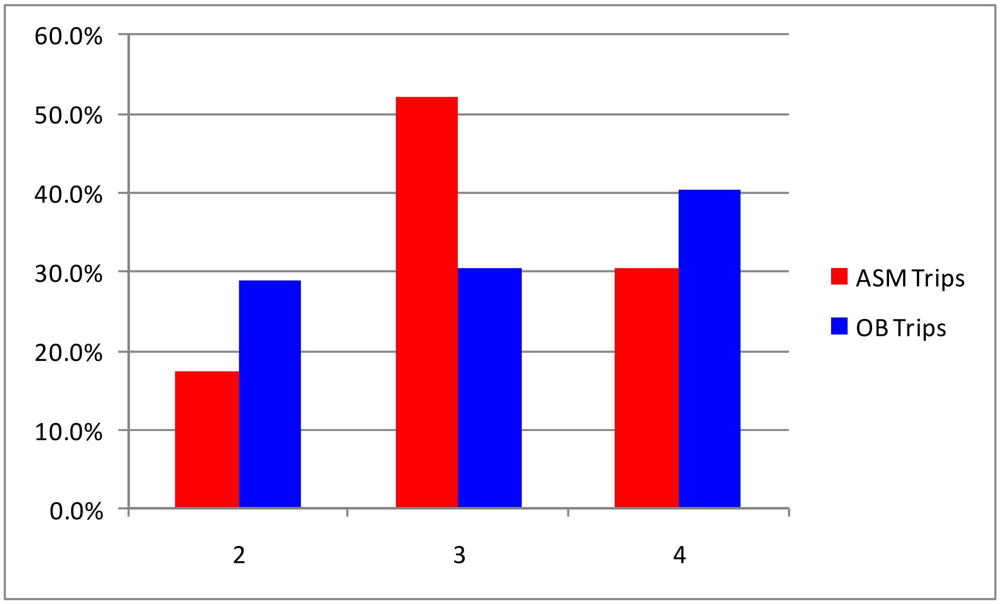


Figure 2. Number of ASM sea days used and trip activity of groundfish trips during May 2010 through early April 2011.

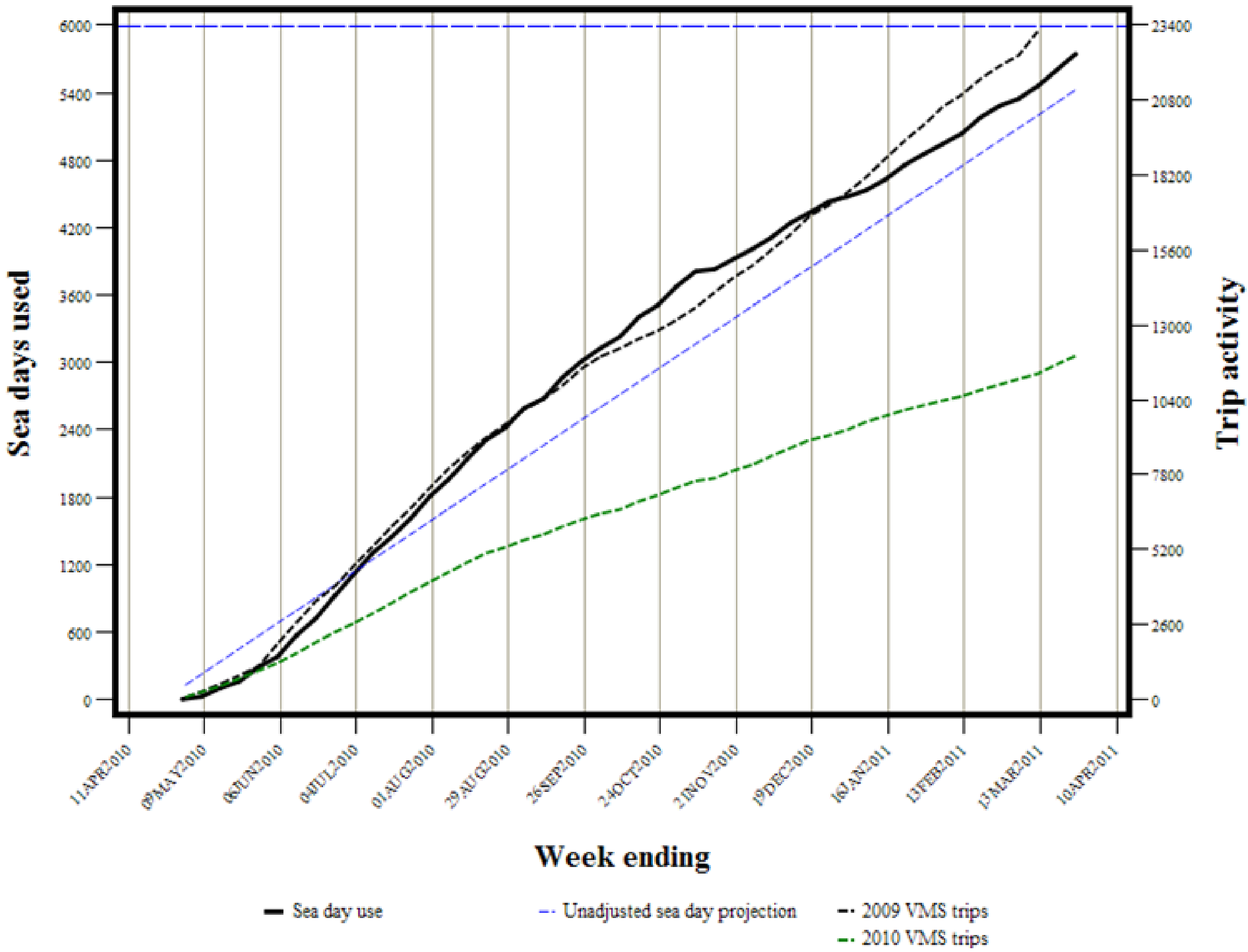


Figure 3. Number of OB sea days used and trip activity of groundfish trips during May 2010 through early April 2011.

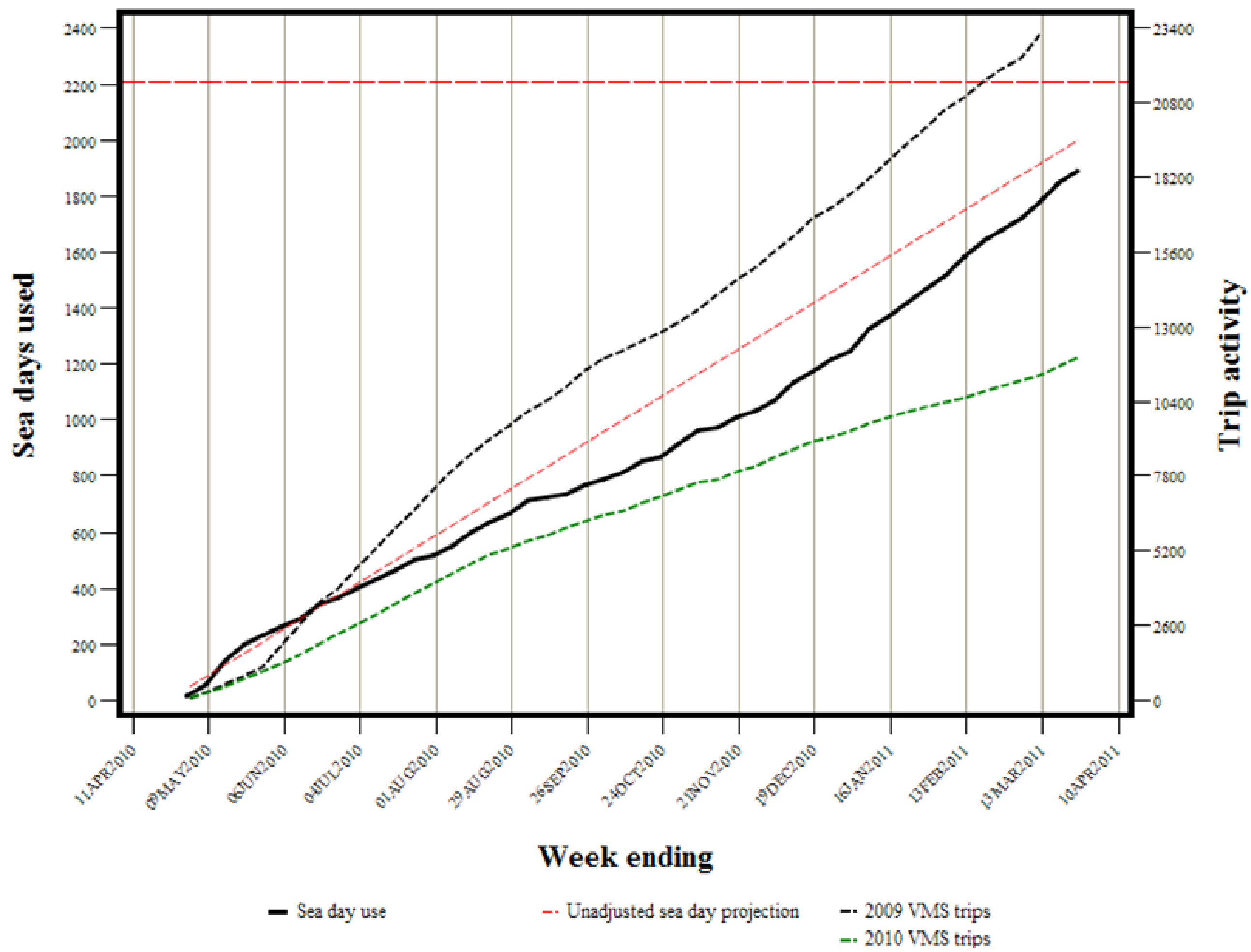
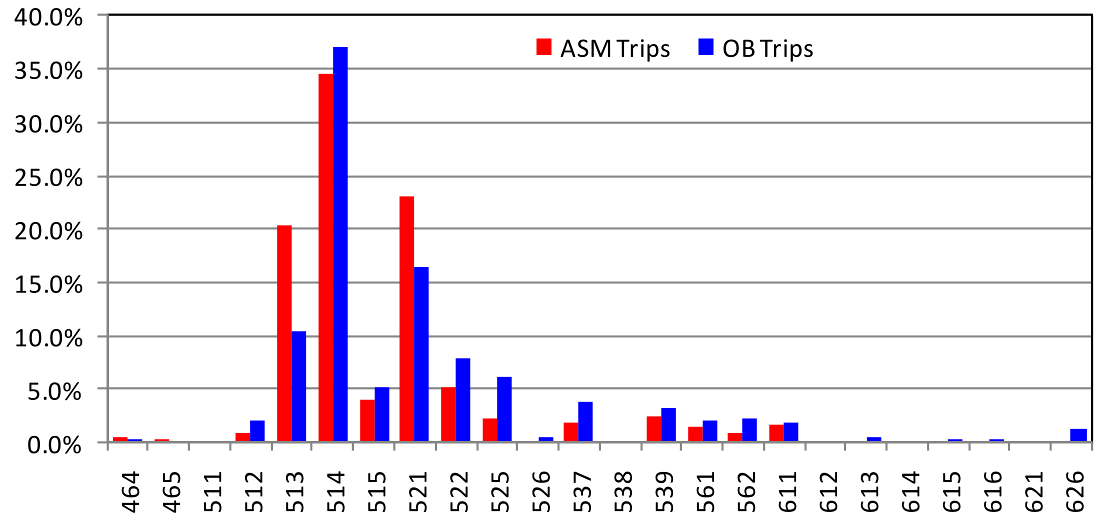


Figure 4. Percentage of NEFOP trips, by dataset (observer, OB and at-sea monitoring ASM) and statistical area (A) and region (B) for groundfish trips from May through December, 2010.



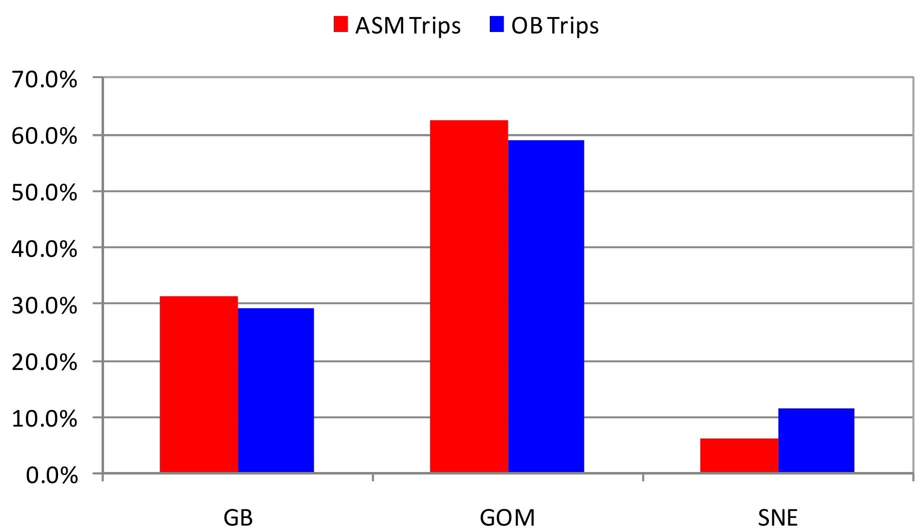


Figure 5. Difference between ASM and Observer discard rates, with 95% confidential interval, for **Gulf of Maine winter flounder** for NEFOP data collection from May through December 2010. Eleven gear/mesh and quarter combinations were evaluated; samples sizes are given by ASM and OB data set.

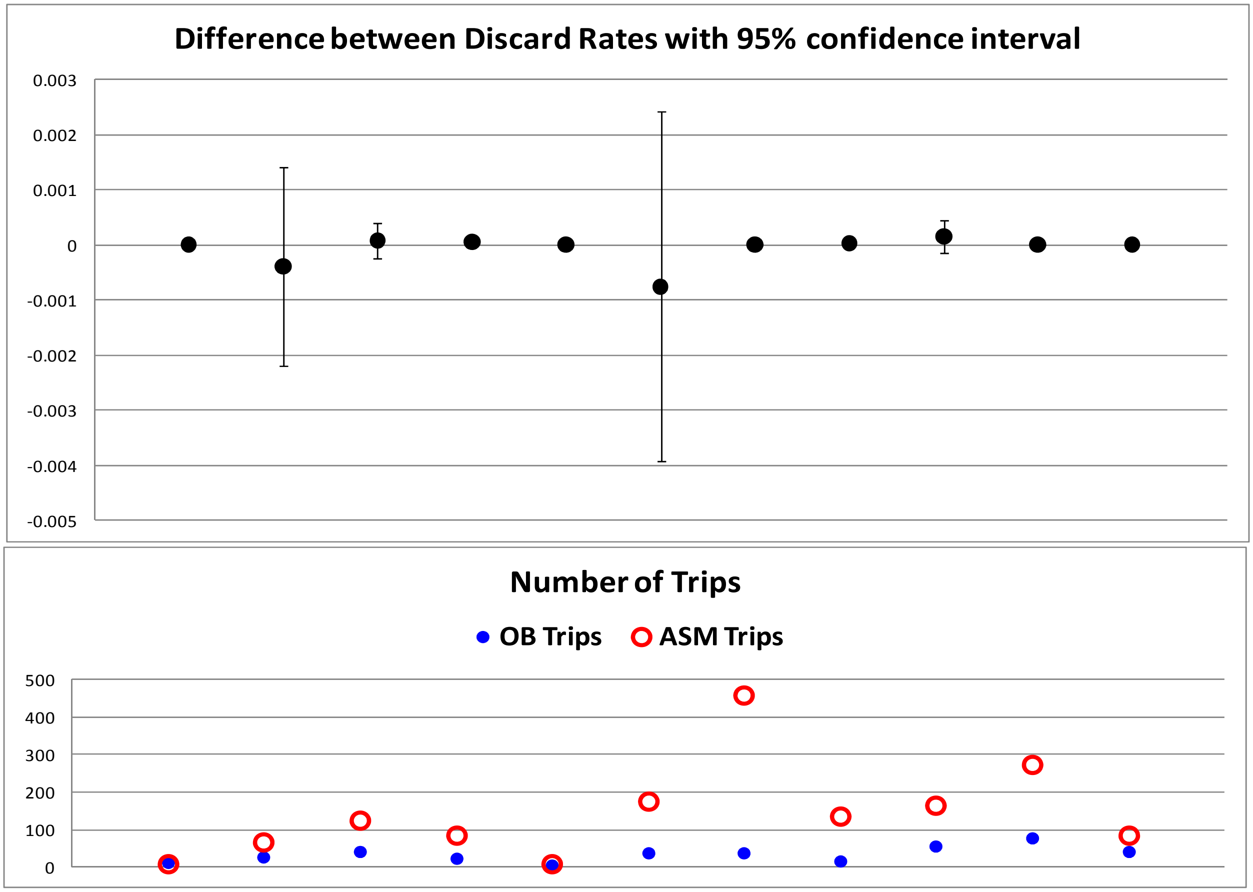
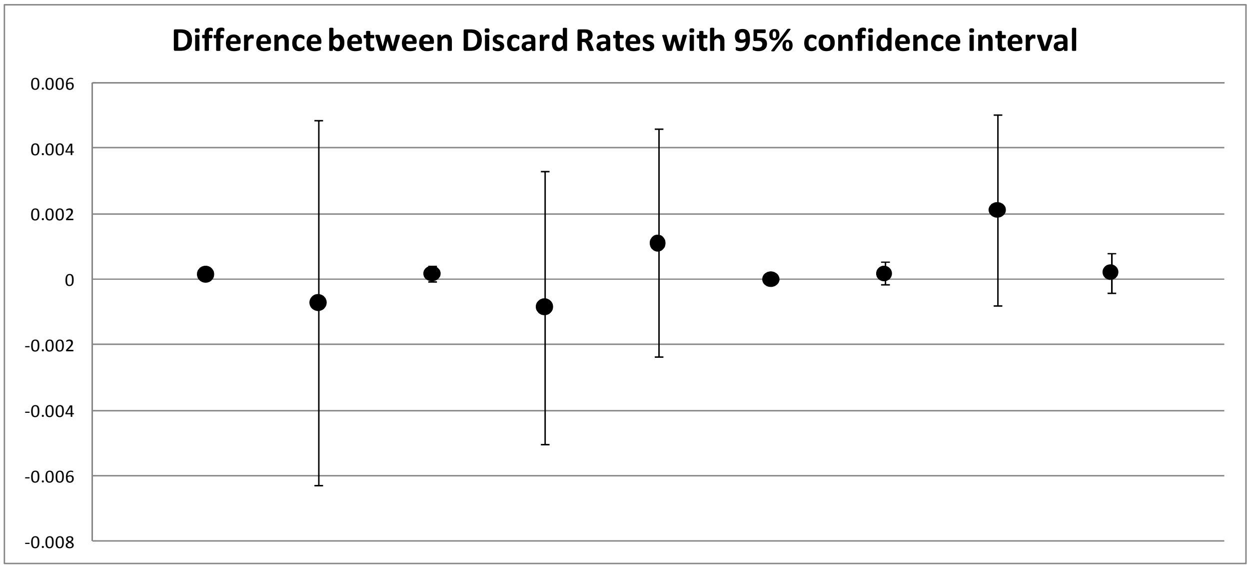


Figure 6. Difference between ASM and Observer discard rate, with 95% confidential interval, for **Georges Bank winter flounder** for NEFOP data collection from May through December 2010. Nine gear/mesh and quarter combinations were evaluated; samples sizes are given by ASM and OB data set.



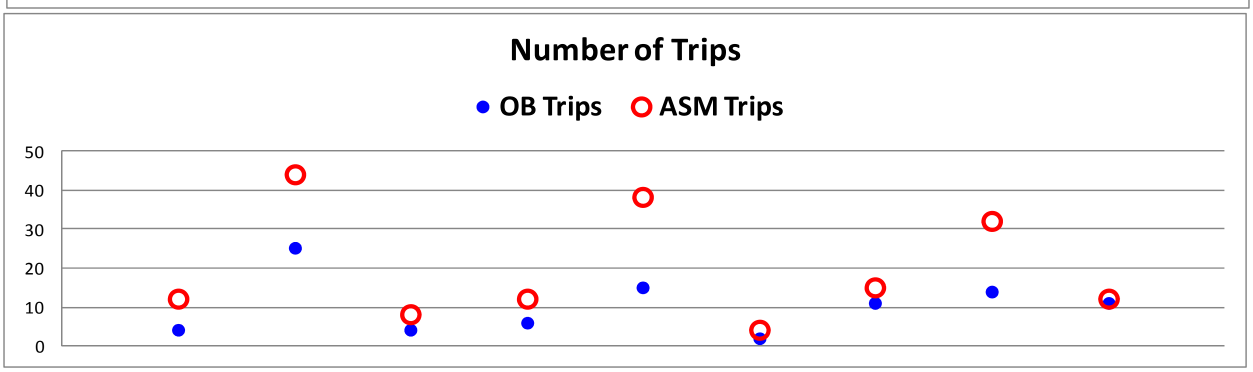


Figure 7. Difference between ASM and Observer discard rate, with 95% confidential interval, for **Southern New England winter flounder** for NEFOP data collection from May through December 2010. Twelve gear/mesh and quarter combinations were evaluated; samples sizes are given by ASM and OB data set.

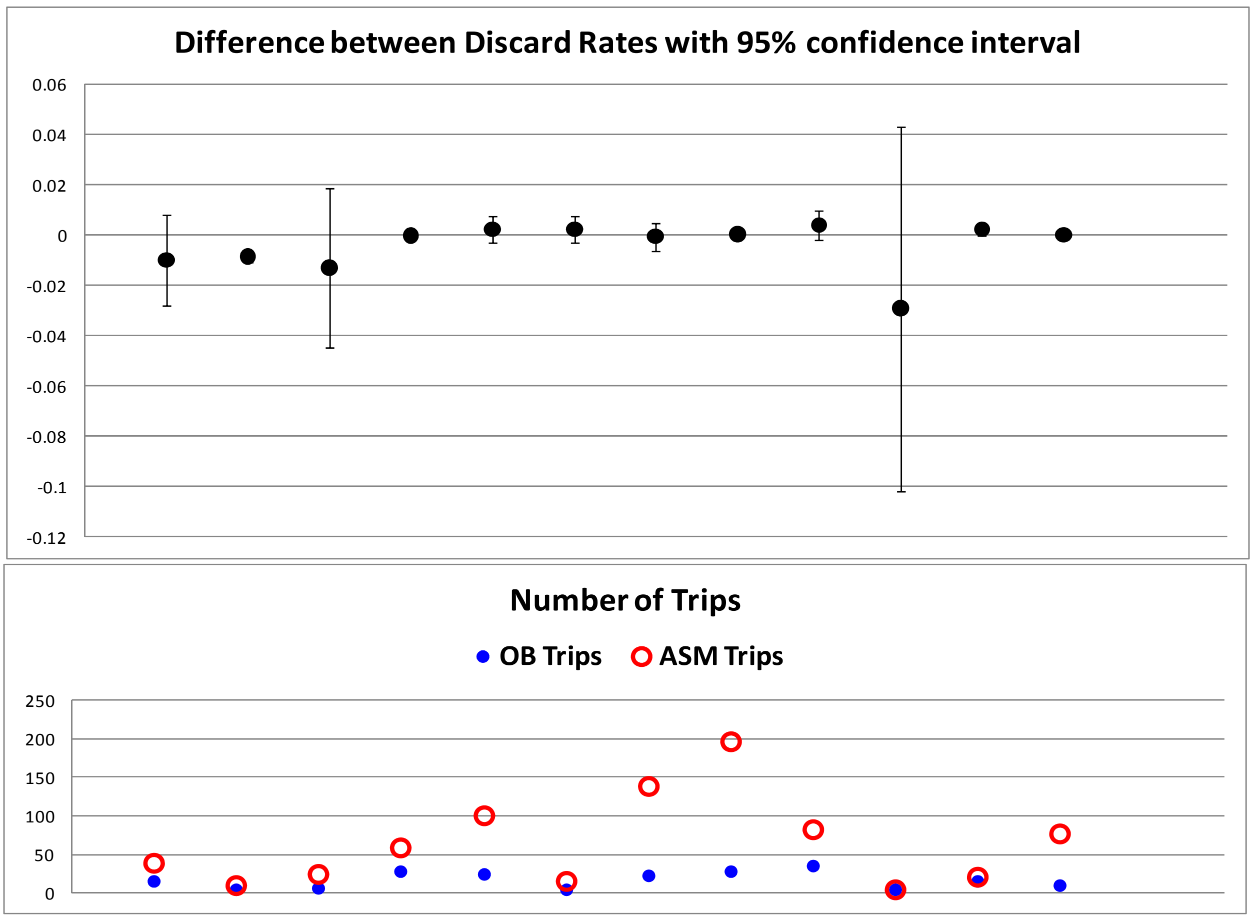
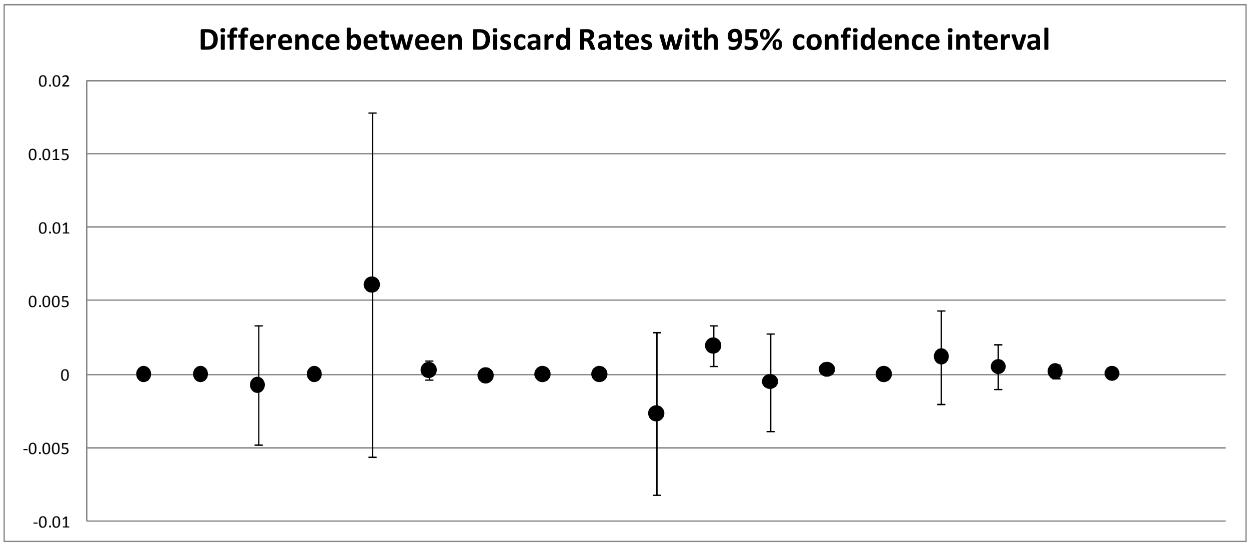


Figure 8. Difference between ASM and Observer discard rate, with 95% confidential interval, for **American plaice** for NEFOP data collection from May through December 2010. Fourteen gear/mesh and quarter combinations were evaluated; samples sizes are given by ASM and OB data set.

15 of 18 cells overlapped zero



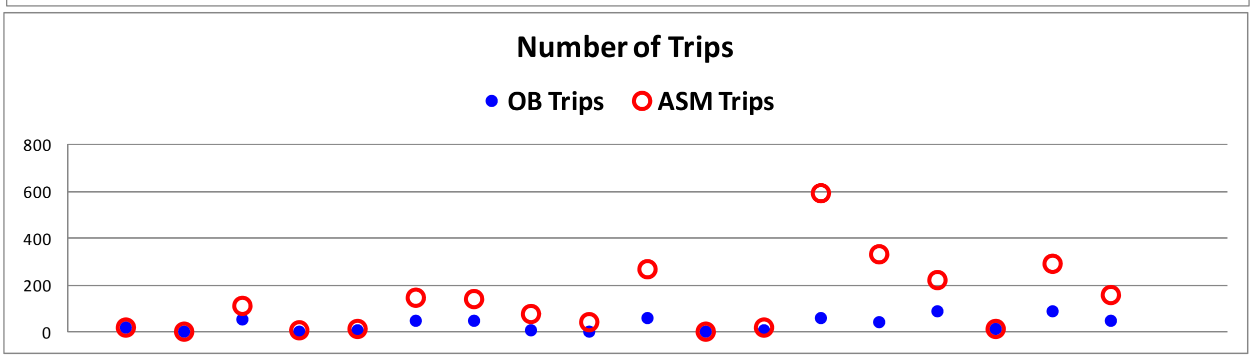


Figure 9. Difference between ASM and Observer discard rate, with 95% confidential interval, for **Gulf of Maine Cod** for NEFOP data collection from May through December 2010. Eleven gear/mesh and quarter combinations were evaluated; samples sizes are given by ASM and OB data set.

10 of 11 cells overlapped zero

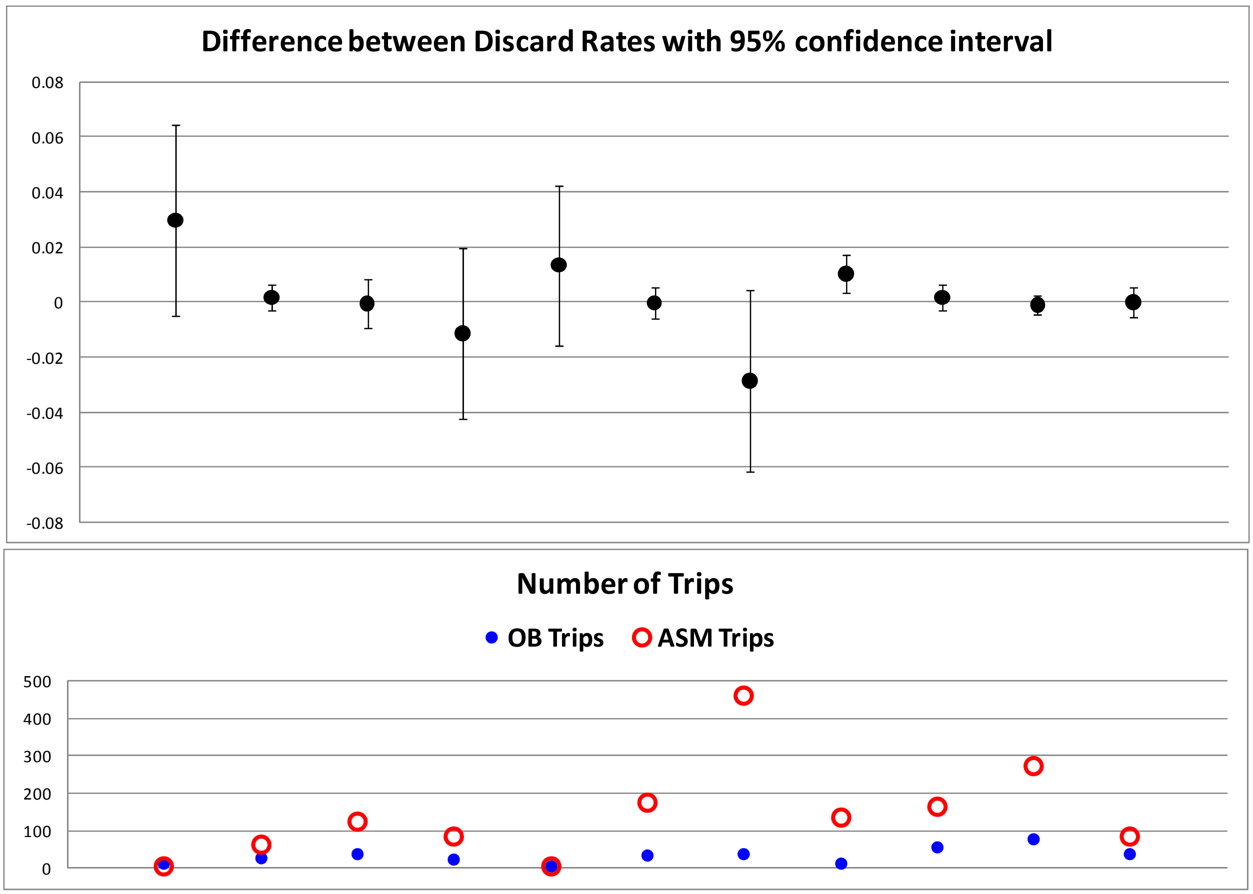


Figure 10. Difference between ASM and Observer discard rate, with 95% confidential interval, for **Eastern Georges Bank Cod** for NEFOP data collection from May through December 2010. Five gear/mesh and quarter combinations were evaluated ; samples sizes are given by ASM and OB data set.

All 5 overlapped zero

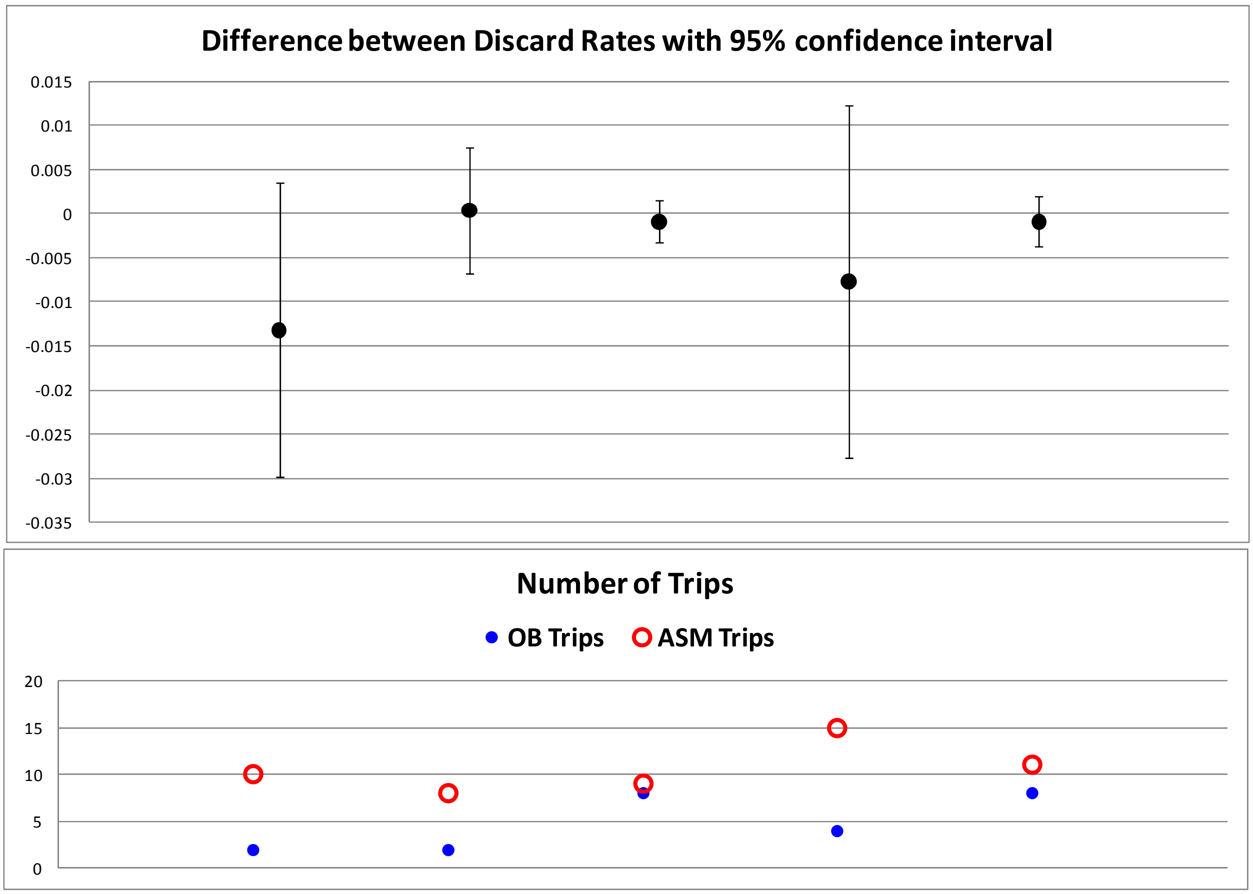


Figure 11 . Difference between ASM and Observer discard rate, with 95% confidential interval, for **Western Georges Bank Cod** for NEFOP data collection from May through December 2010. Fourteen gear/mesh and quarter combinations were evaluated ; samples sizes are given by ASM and OB data set.

13 of 14 cells overlapped zero

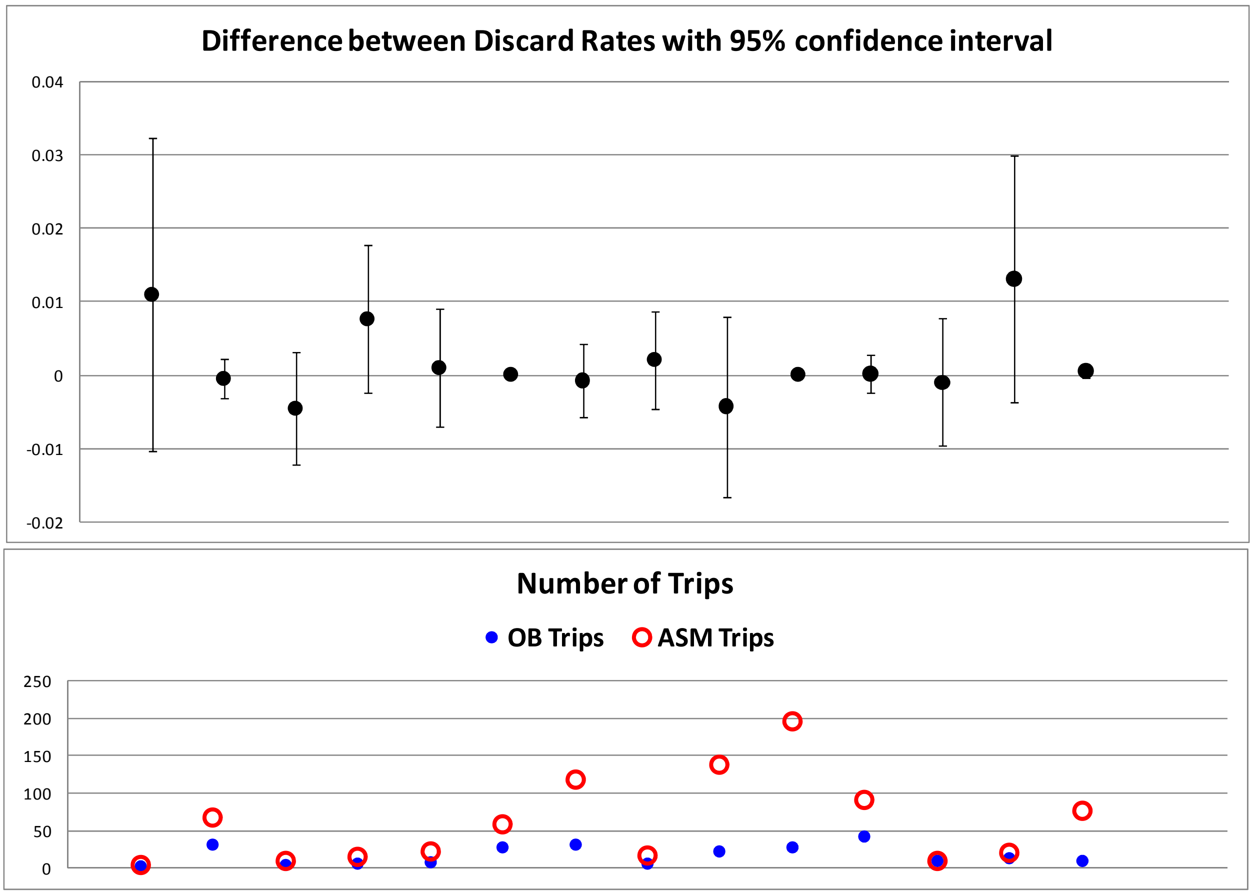


Figure 12. Difference between ASM and Observer discard rate, with 95% confidential interval, for **Gulf of Maine Haddock** for NEFOP data collection from May through December 2010. Eleven gear/mesh and quarter combinations were evaluated ; samples sizes are given by ASM and OB data set.

9 of 11 cells overlapped zero

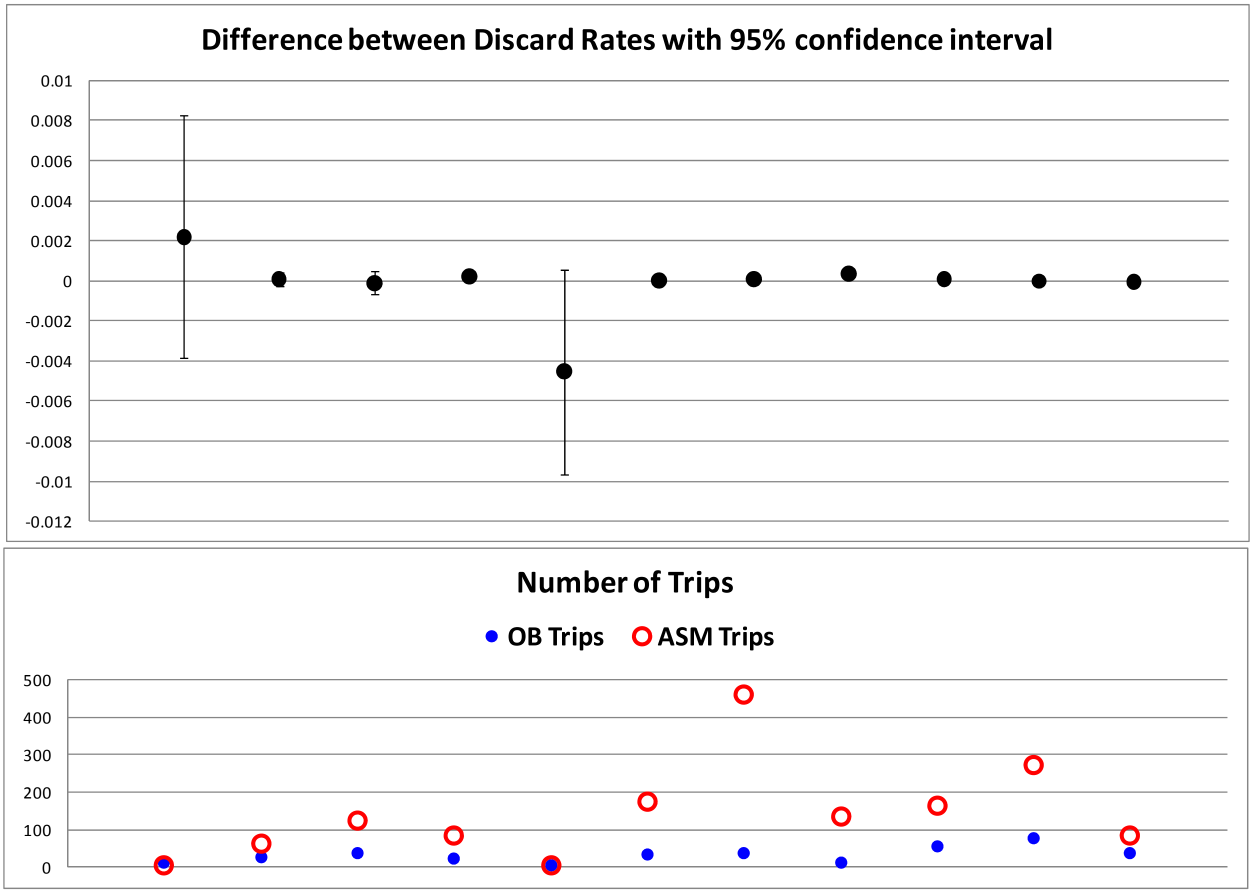


Figure 13. Difference between ASM and Observer discard rate, with 95% confidential interval, for **Eastern Georges Bank Haddock** for NEFOP data collection from May through December 2010. Five gear/mesh and quarter combinations were evaluated ; samples sizes are given by ASM and OB data set.

All 5 cells overlapped zero

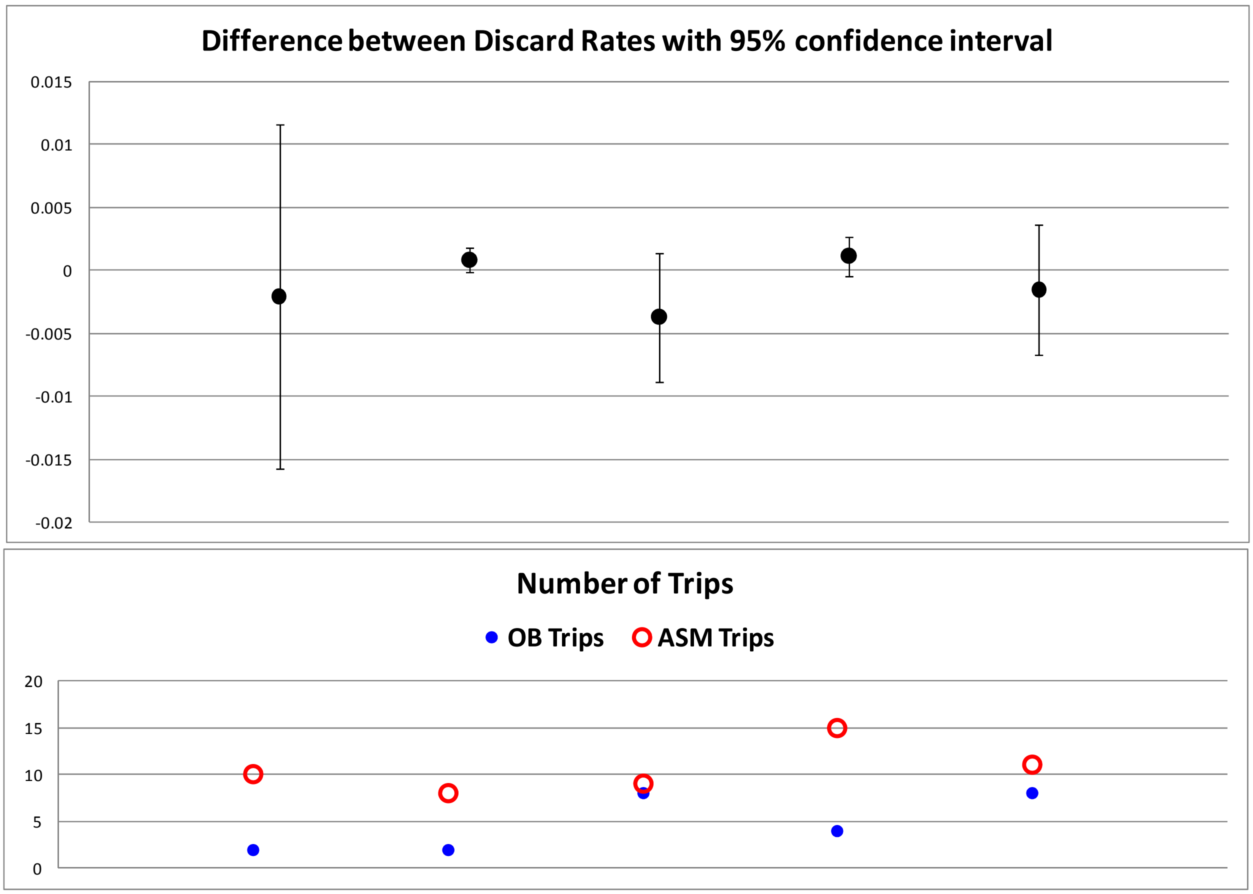
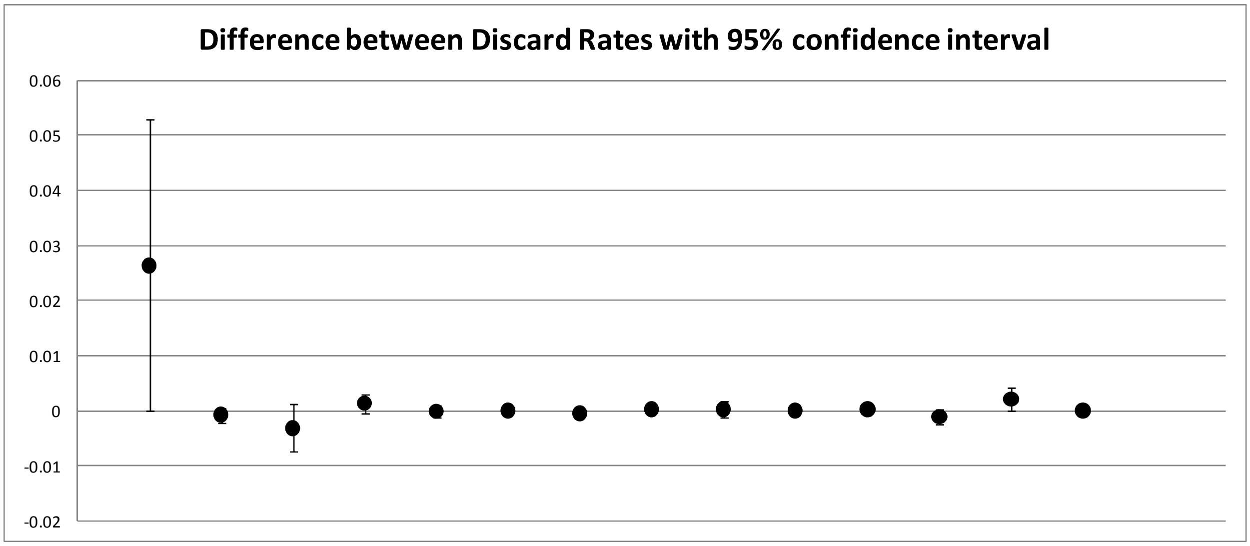


Figure 14. Difference between ASM and Observer discard rate, with 95% confidential interval, for **Western Georges Bank Haddock** for NEFOP data collection from May through December 2010. Fourteen gear/mesh and quarter combinations were evaluated ; samples sizes are given by ASM and OB data set.

12 of 14 cells overlapped zero



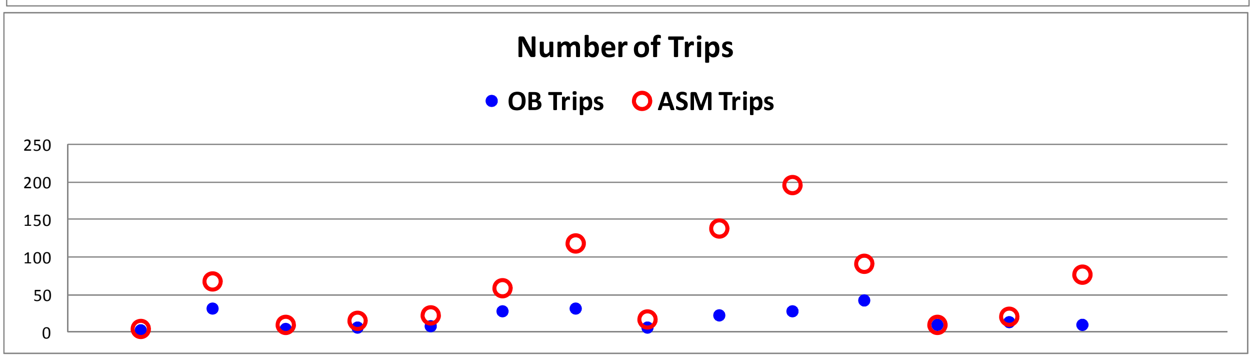


Figure15. Difference between ASM and Observer discard rate, with 95% confidential interval, for **Atlantic halibut** for NEFOP data collection from May through December 2010. Eighteen gear/mesh and quarter combinations were evaluated; samples sizes are given by ASM and OB data set.

14 of 18 cells overlapped zero

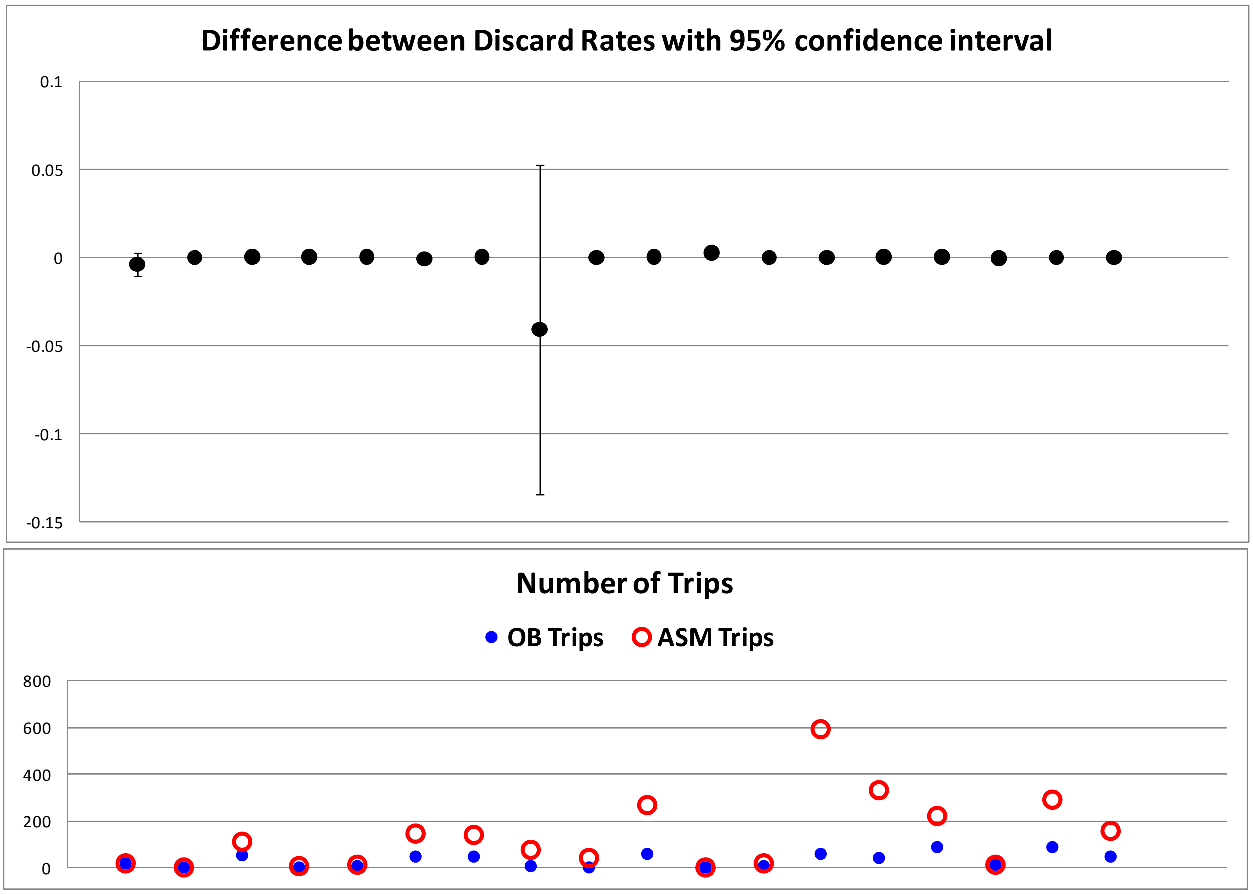


Figure 16. Difference between ASM and Observer discard rate, with 95% confidential interval, for **Southern monkfish** for NEFOP data collection from May through December 2010. Ten gear/mesh and quarter combinations were evaluated; samples sizes are given by ASM and OB data set.

All 10 cells overlapped zero

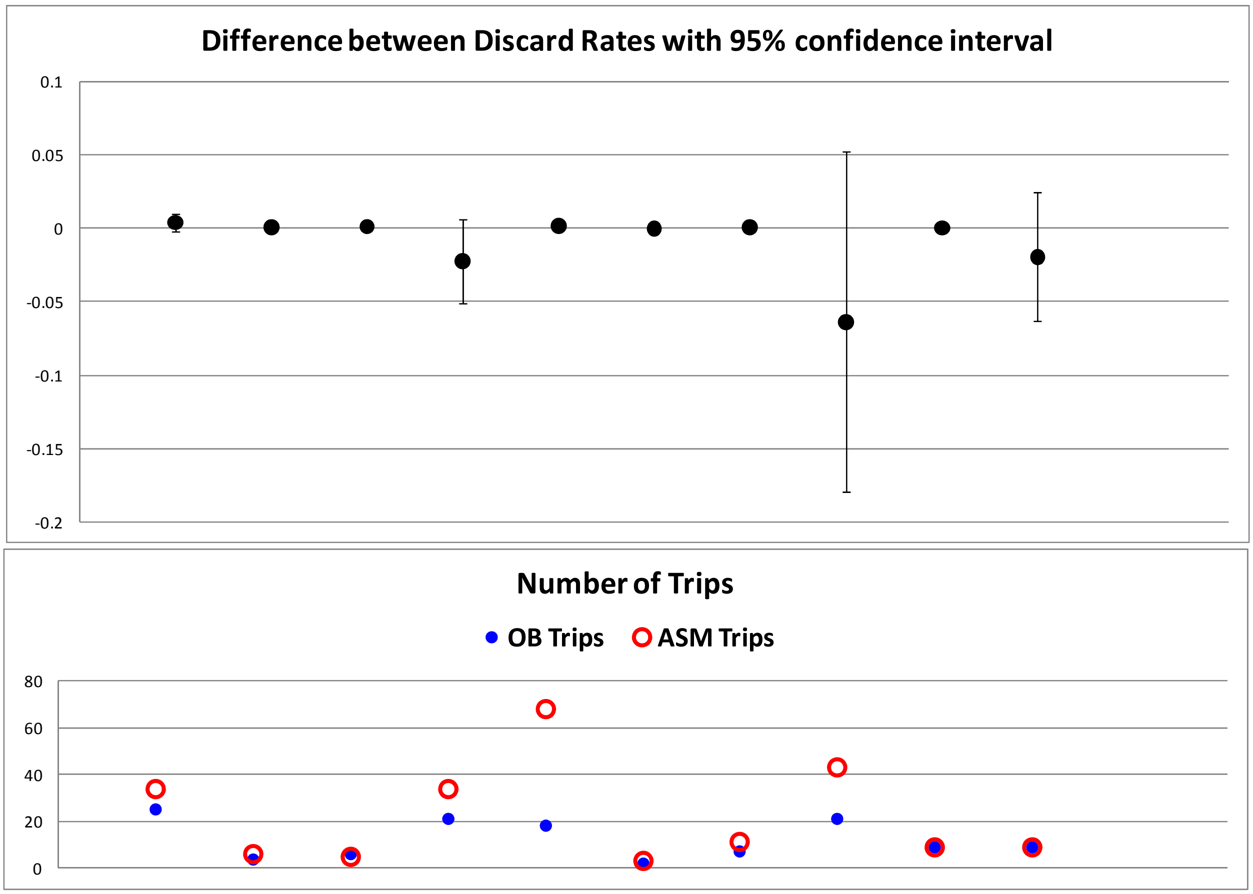
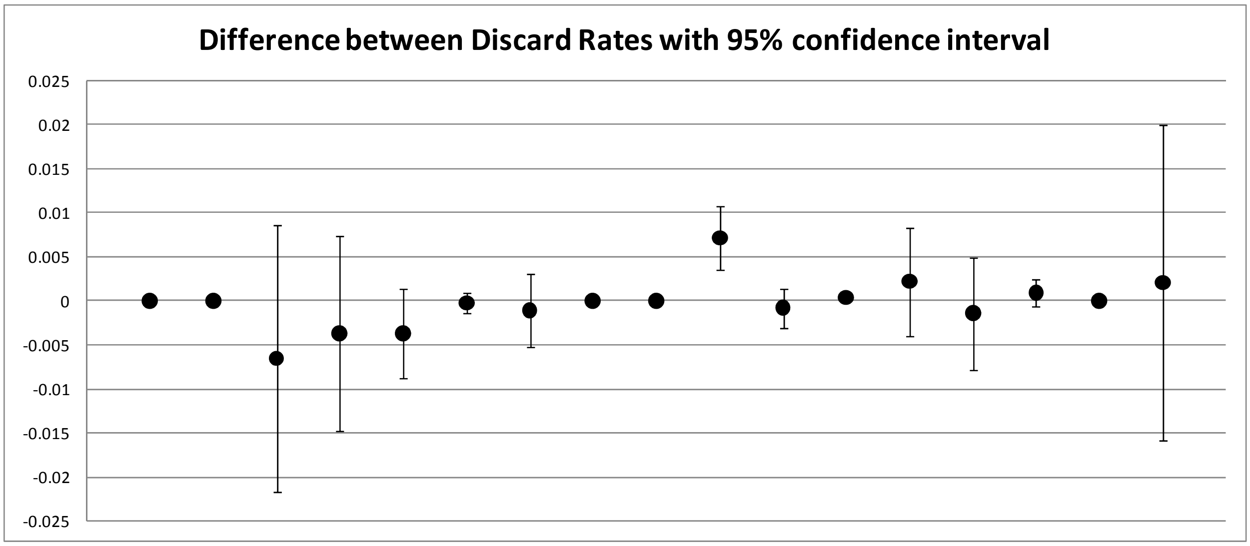


Figure 17. Difference between ASM and Observer discard rate, with 95% confidential interval, for **Northern monkfish** for NEFOP data collection from May through December 2010. Seventeen gear/mesh and quarter combinations were evaluated; samples sizes are given by ASM and OB data set.

16 of 17 cells overlapped zero



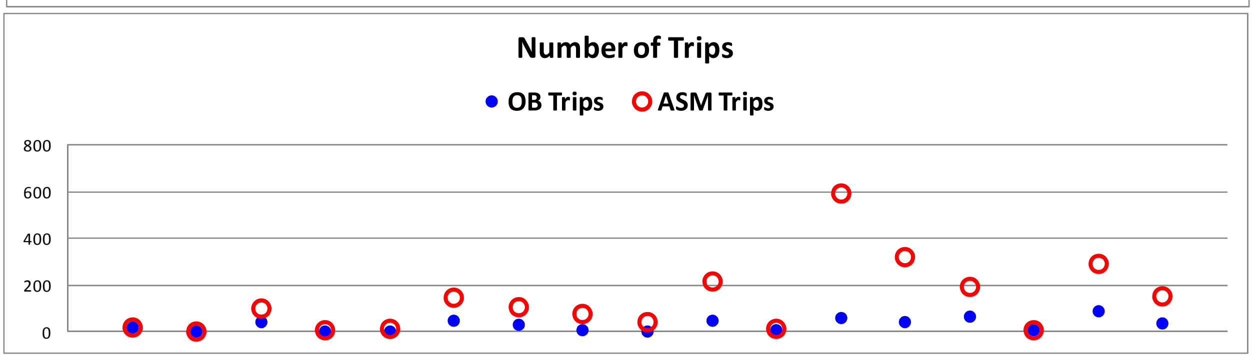
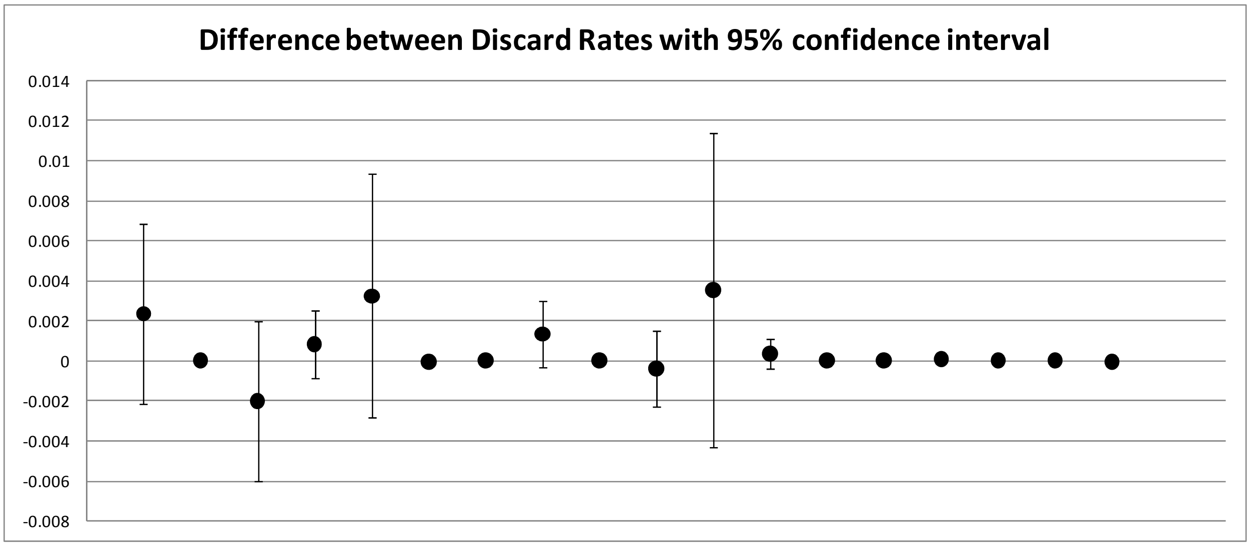


Figure 18. Difference between ASM and Observer discard rate, with 95% confidential interval, for **ocean pout** for NEFOP data collection from May through December 2010. eighteen gear/mesh and quarter combinations were evaluated; samples sizes are given by ASM and OB data set.

All 18 cells overlapped zero



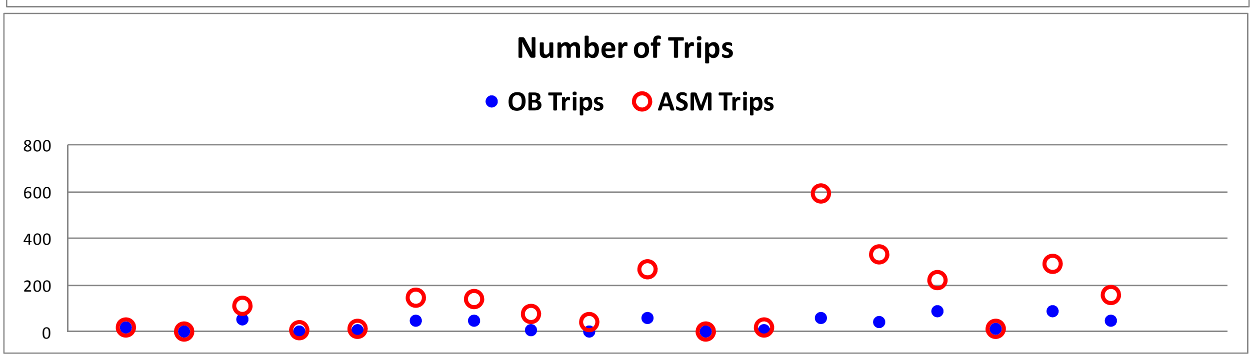
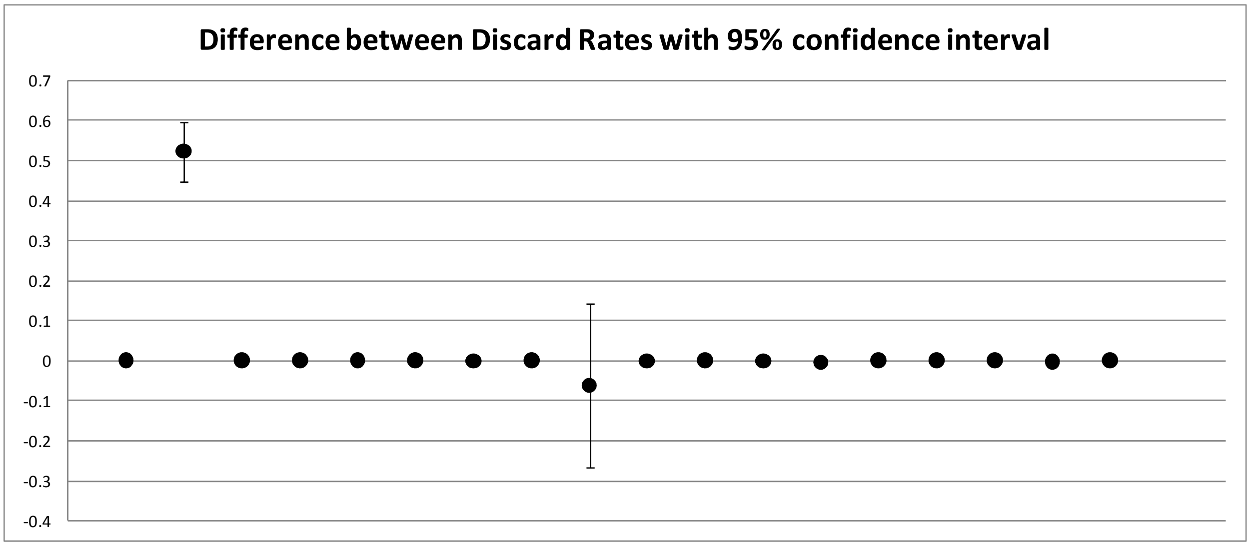


Figure 19. Difference between ASM and Observer discard rate, with 95% confidential interval, for **pollock** for NEFOP data collection from May through December 2010. Eighteen gear/mesh and quarter combinations were evaluated; samples sizes are given by ASM and OB data set.

15 of 18 cells overlapped zero



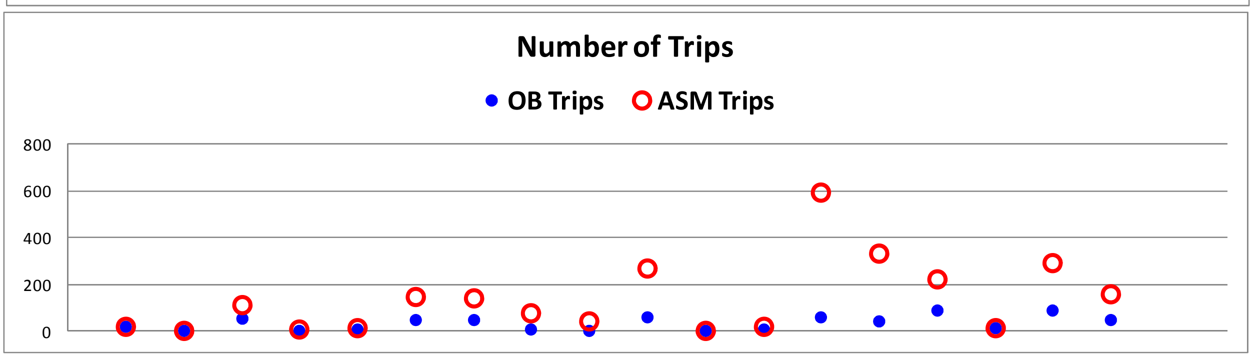
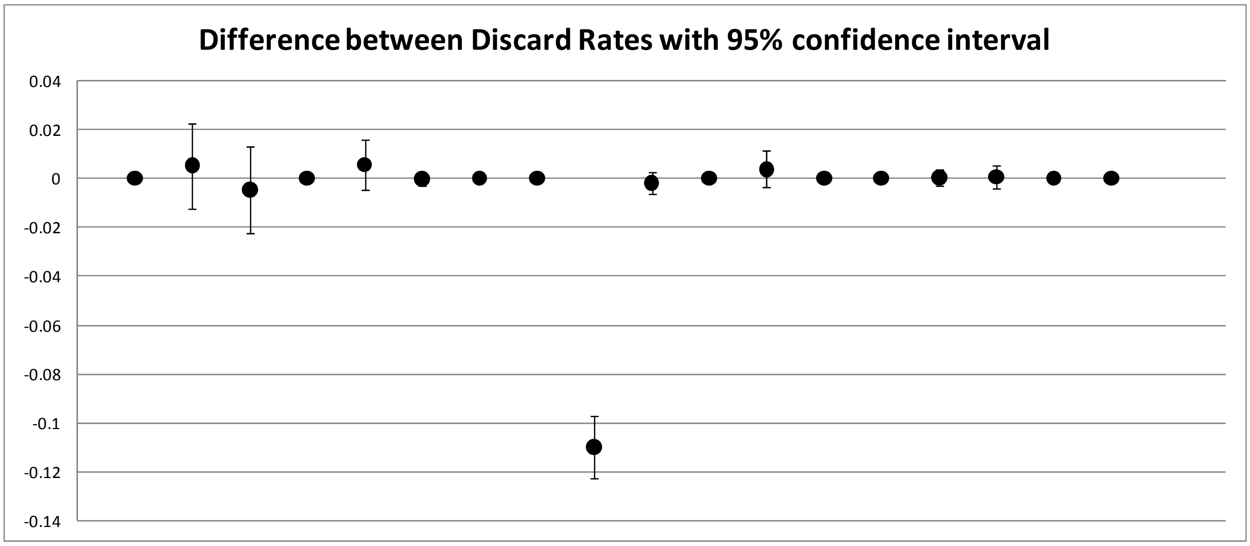


Figure 20. Difference between ASM and Observer discard rate, with 95% confidential interval, for **redfish** for NEFOP data collection from May through December 2010. Eighteen gear/mesh and quarter combinations were evaluated; samples sizes are given by ASM and OB data set.

17of 18 cells overlapped zero



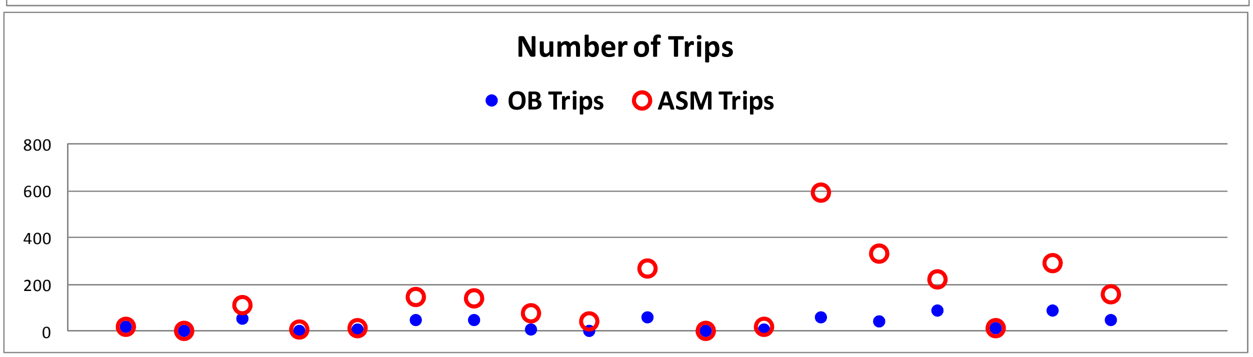
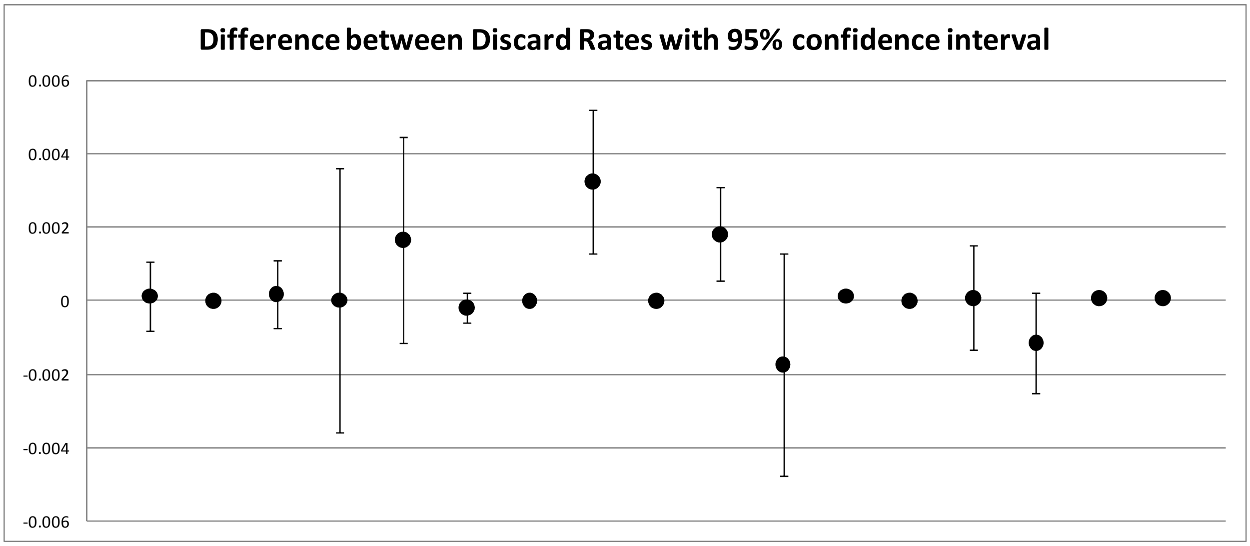


Figure 21. Difference between ASM and Observer discard rate, with 95% confidential interval, for **northern red hake** for NEFOP data collection from May through December 2010. Seventeen gear/mesh and quarter combinations were evaluated; samples sizes are given by ASM and OB data set.

14 of 17 cells overlapped zero



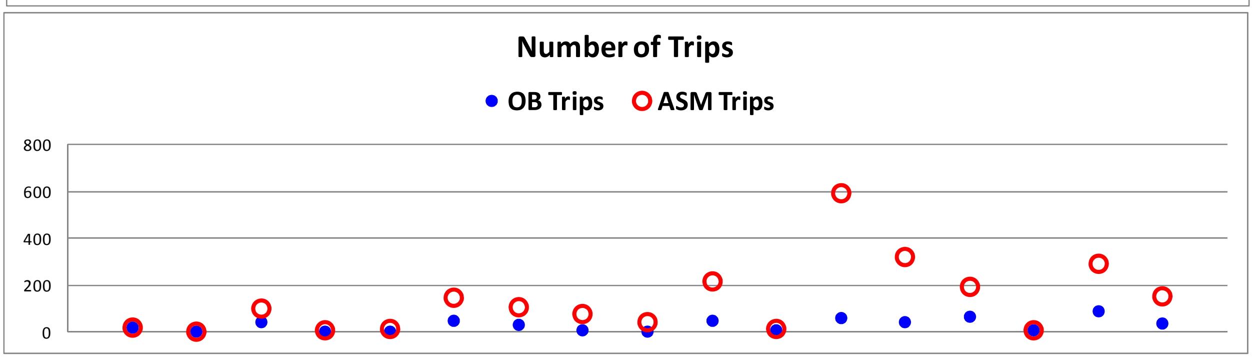
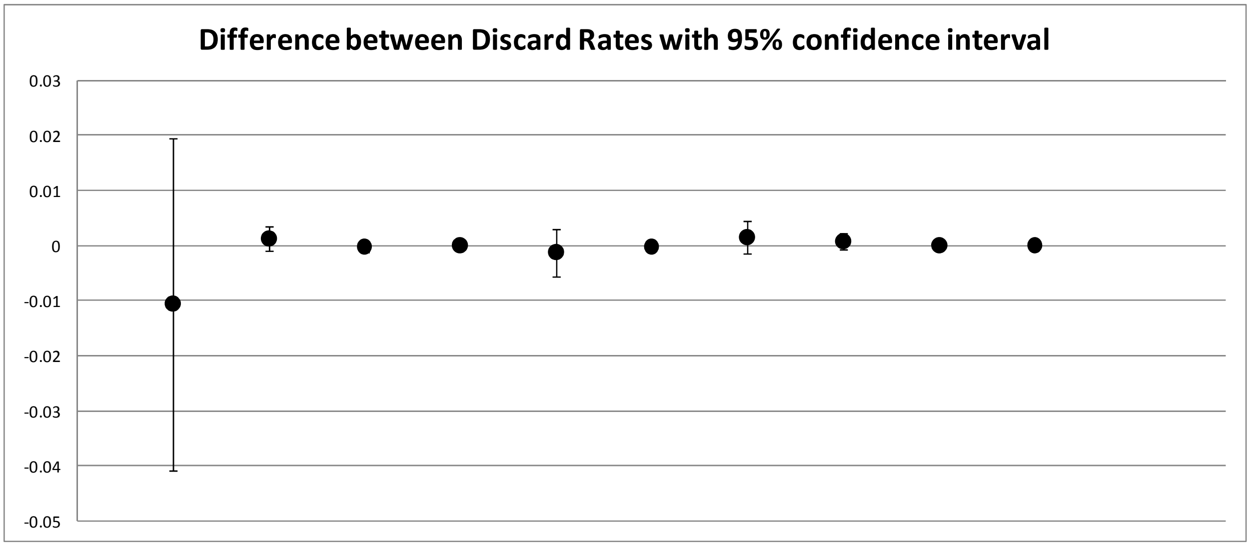


Figure22 . Difference between ASM and Observer discard rate, with 95% confidential interval, for **southern red hake** for NEFOP data collection from May through December 2010. Ten gear/mesh and quarter combinations were evaluated; samples sizes are given by ASM and OB data set.

9 of 10 cells overlapped zero



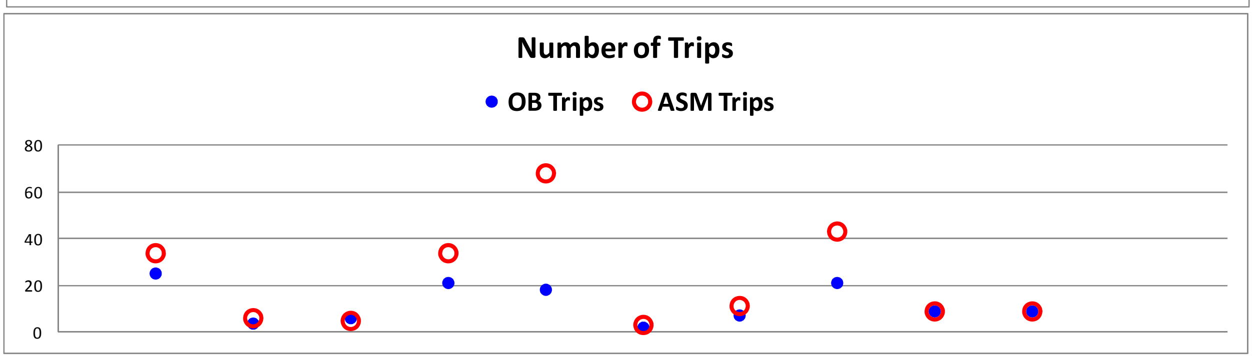


Figure 23. Difference between ASM and Observer discard rate, with 95% confidential interval, for **sea scallop** for NEFOP data collection from May through December 2010. Eighteen gear/mesh and quarter combinations were evaluated; samples sizes are given by ASM and OB data set.

all 18 cells overlapped zero

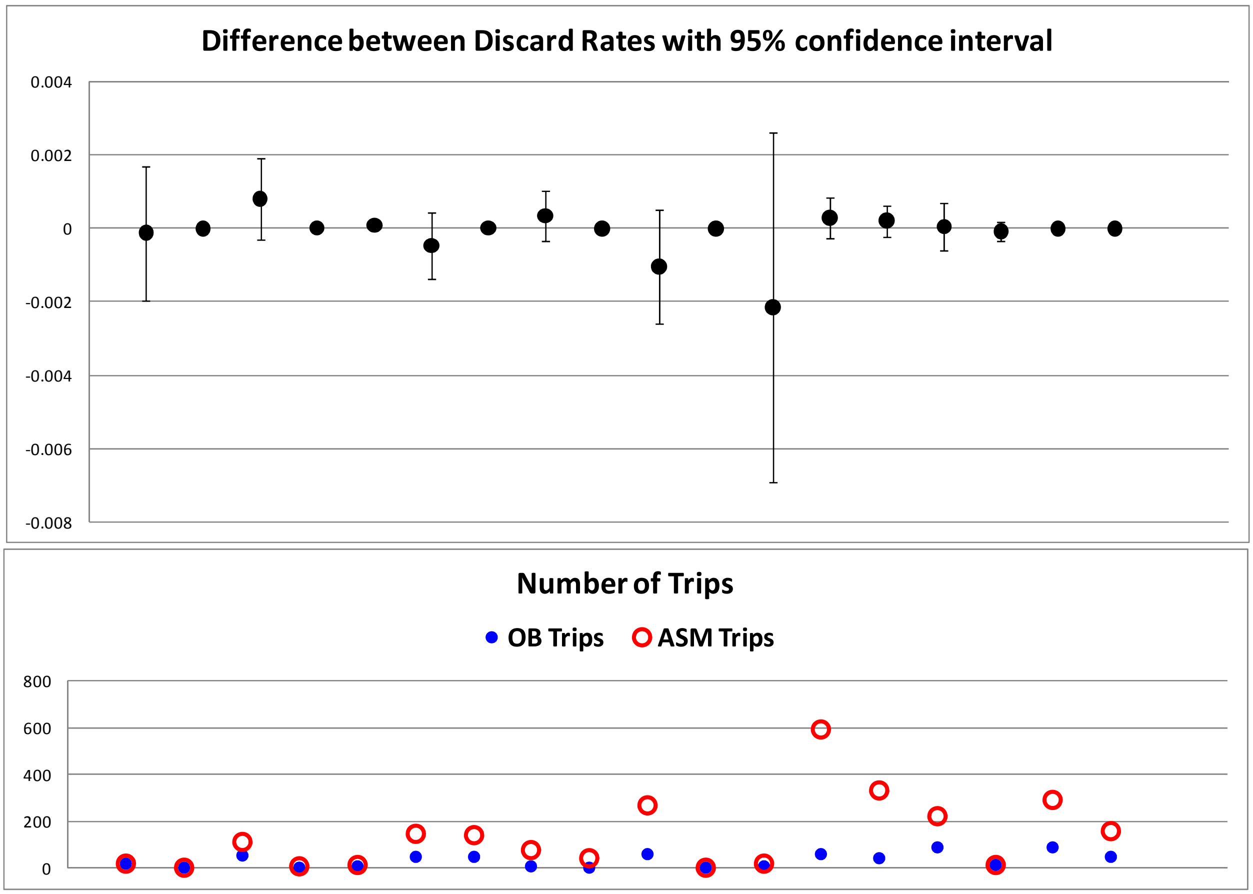
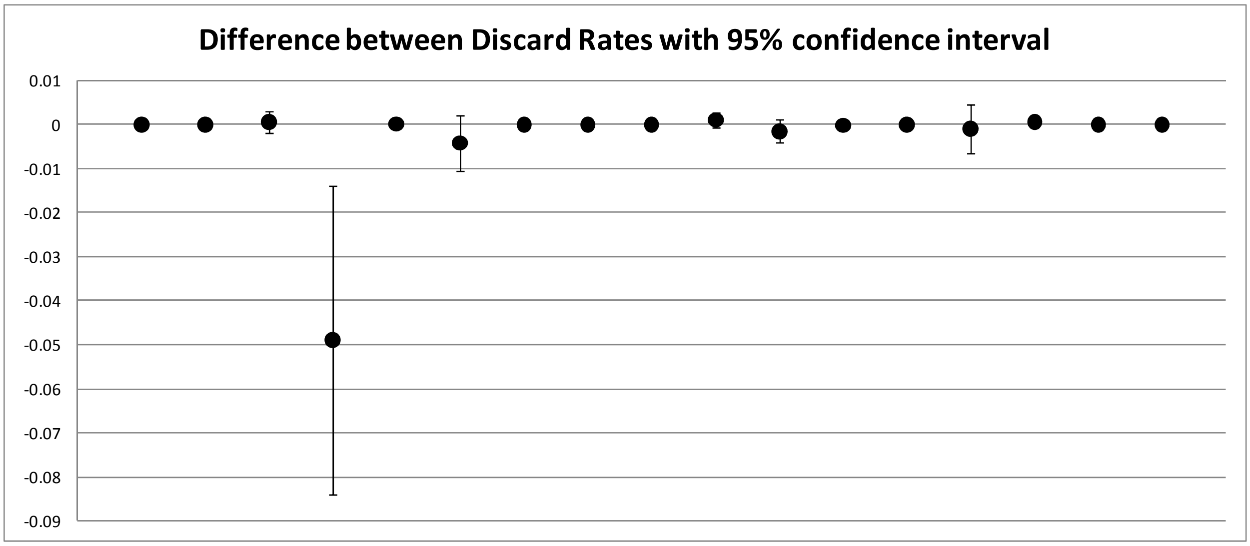


Figure 24. Difference between ASM and Observer discard rate, with 95% confidential interval, for **northern silver hake** for NEFOP data collection from May through December 2010. Seventeen gear/mesh and quarter combinations were evaluated; samples sizes are given by ASM and OB data set.

15 of 17 cells overlapped zero



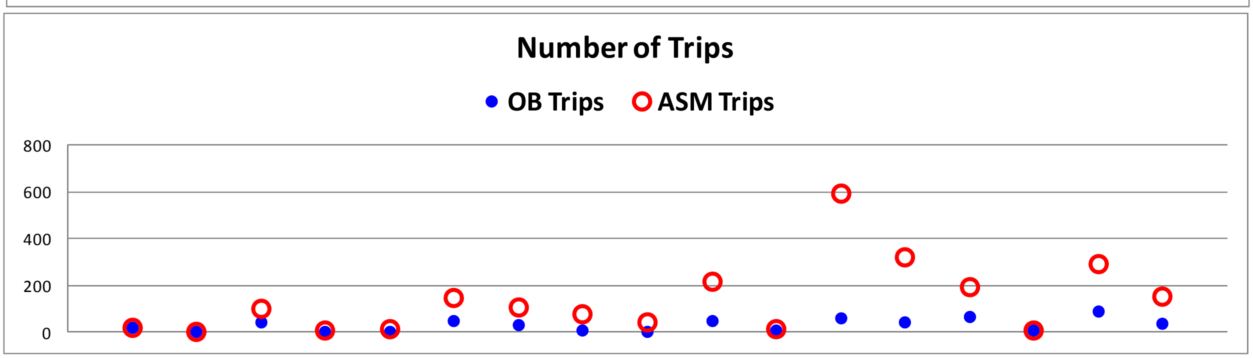
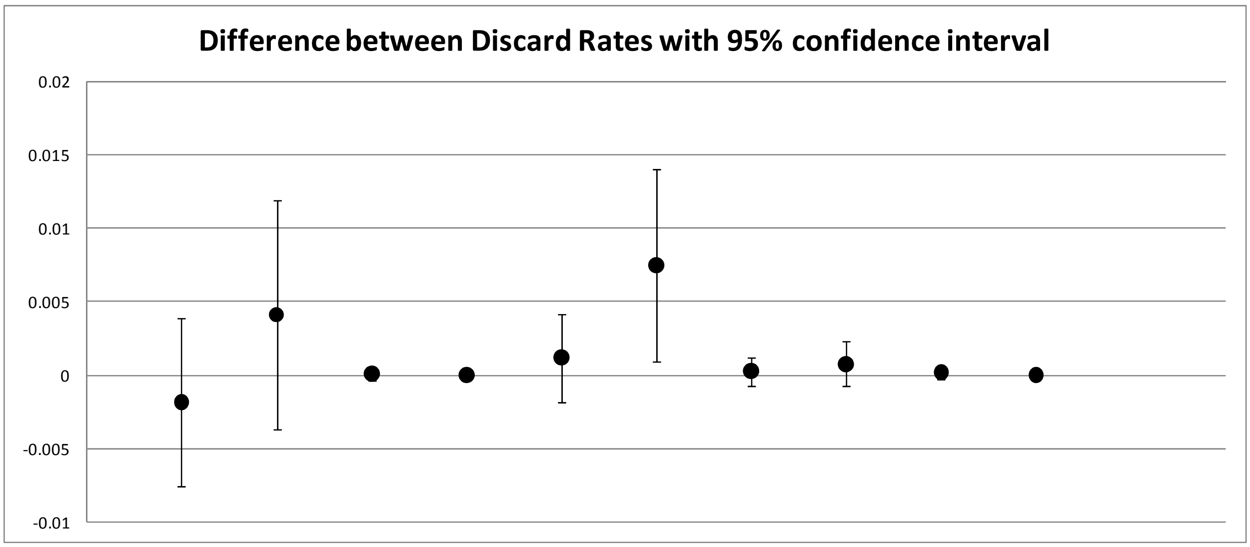


Figure 25. Difference between ASM and Observer discard rate, with 95% confidential interval, for **southern silver hake** for NEFOP data collection from May through December 2010. Ten gear/mesh and quarter combinations were evaluated; samples sizes are given by ASM and OB data set.

9 of 10 cells overlapped zero



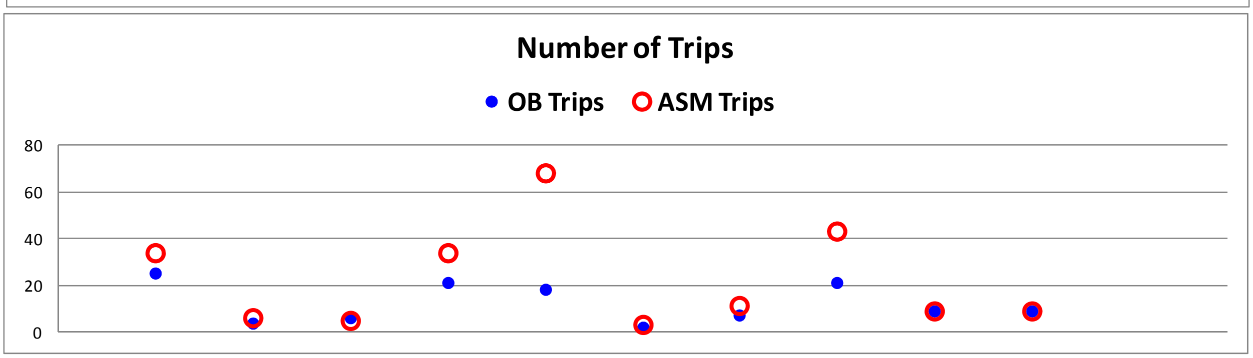
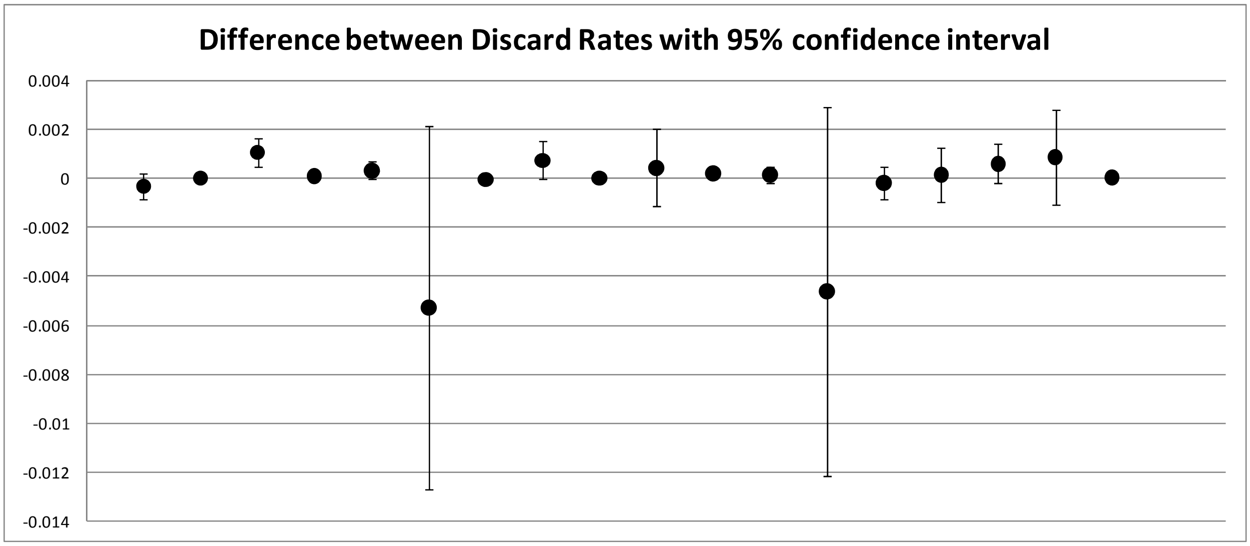


Figure 26. Difference between ASM and Observer discard rate, with 95% confidential interval, for **white hake** for NEFOP data collection from May through December 2010. Eighteen gear/mesh and quarter combinations were evaluated; samples sizes are given by ASM and OB data set.

15 of 18 cells overlapped zero



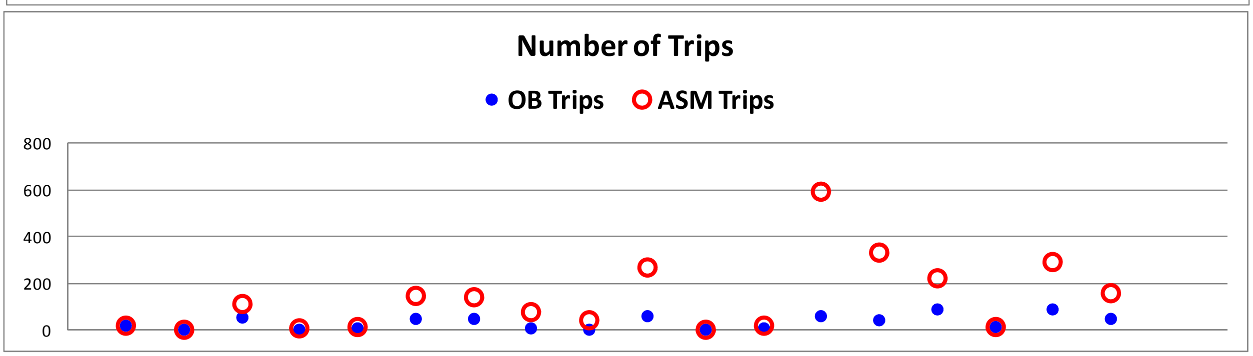


Figure 27. Difference between ASM and Observer discard rate, with 95% confidential interval, for **northern windowpane flounder** for NEFOP data collection from May through December 2010. Eighteen gear/mesh and quarter combinations were evaluated; samples sizes are given by ASM and OB data set.

all 18 cells overlapped zero

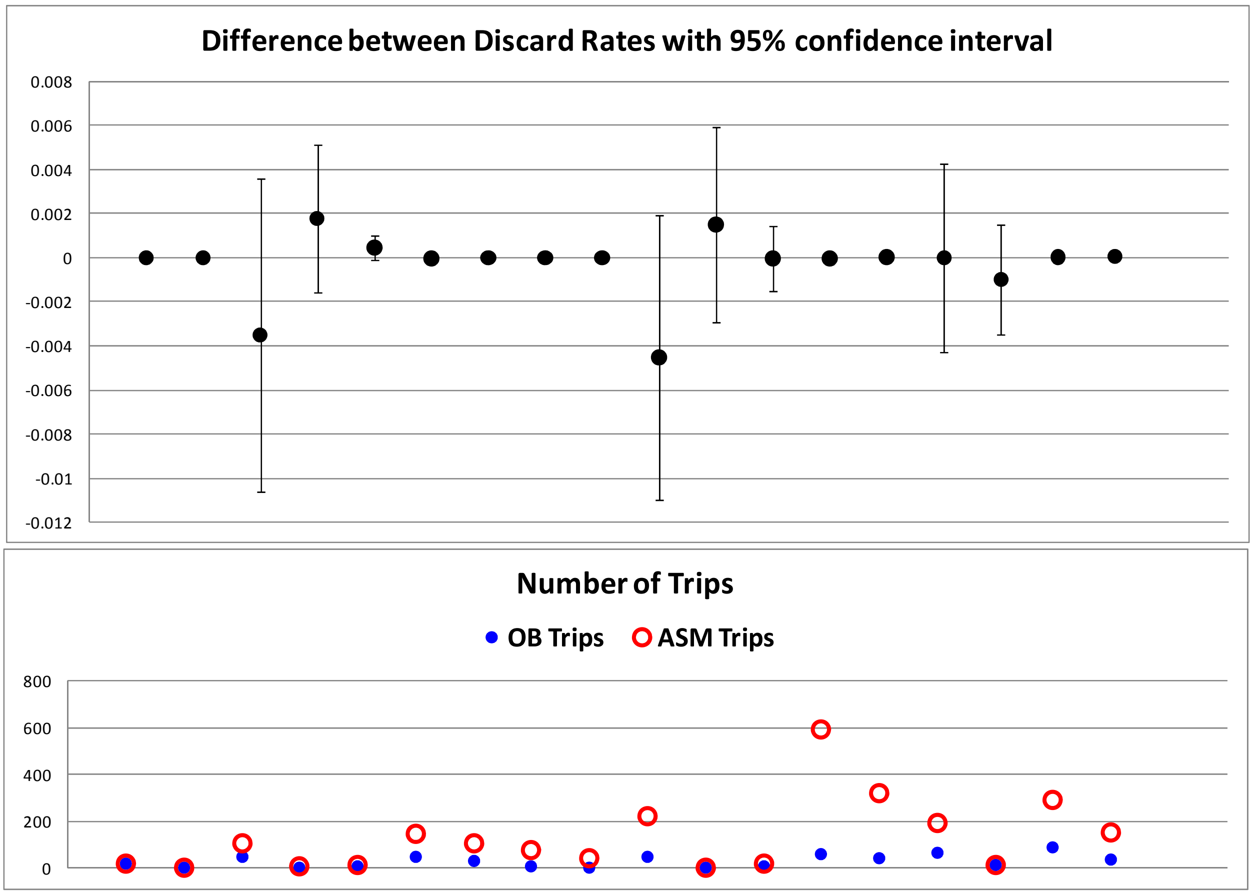


Figure 28. Difference between ASM and Observer discard rate, with 95% confidential interval, for **southern windowpane flounder** for NEFOP data collection from May through December 2010. Five gear/mesh and quarter combinations were evaluated; samples sizes are given by ASM and OB data set.

All 5cells overlapped zero

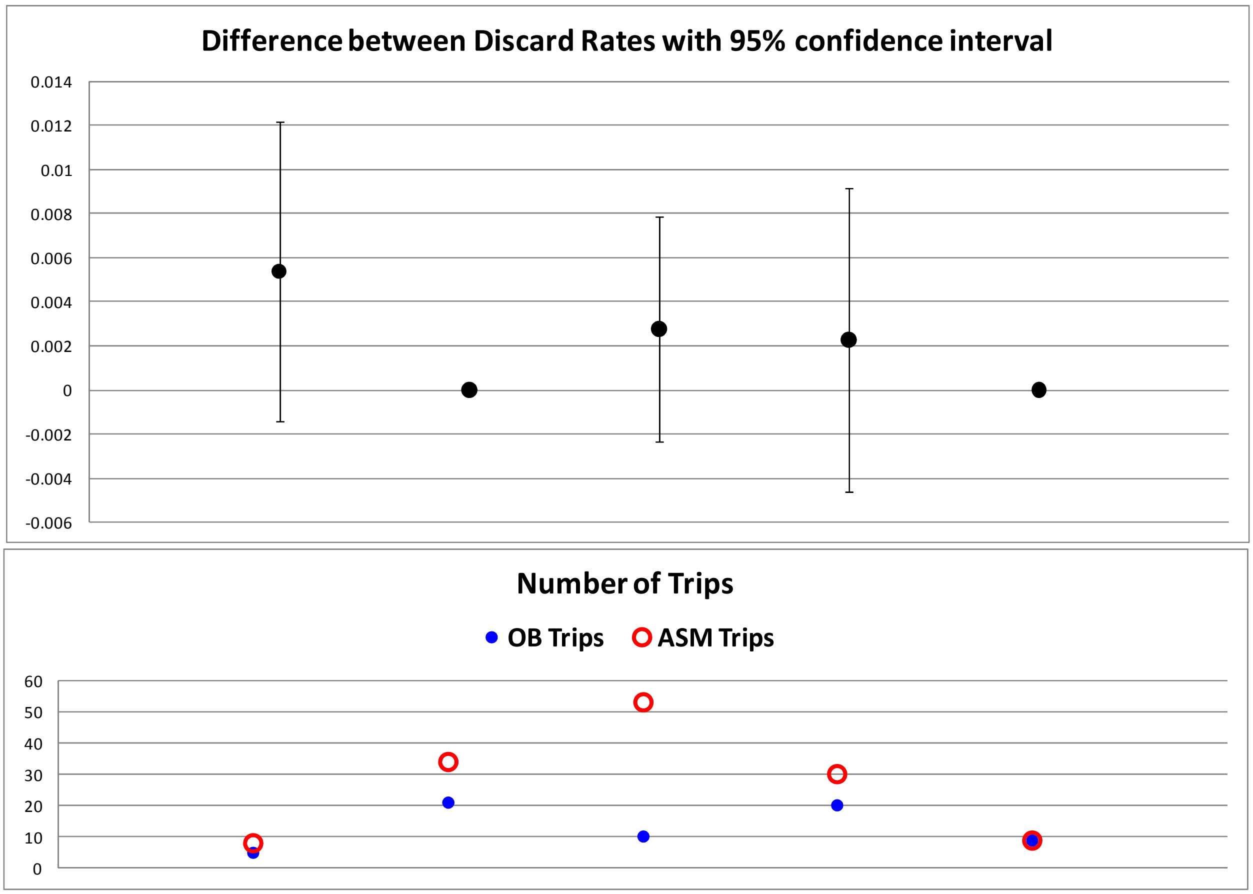


Figure 29. Difference between ASM and Observer discard rate, with 95% confidential interval, for **witch flounder** for NEFOP data collection from May through December 2010. Eighteen gear/mesh and quarter combinations were evaluated; samples sizes are given by ASM and OB data set.

16 of 18 cells overlapped zero

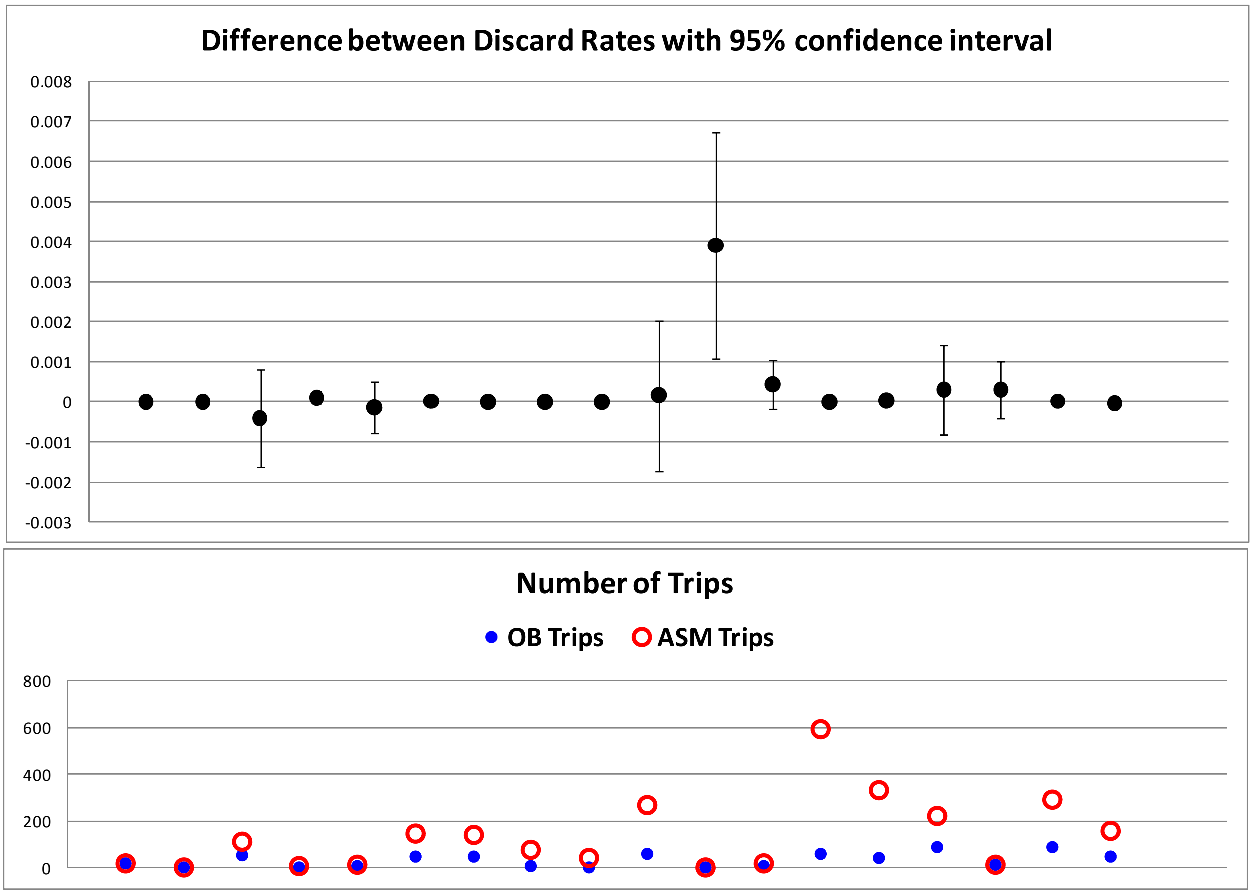


Figure 30. Difference between ASM and Observer discard rate, with 95% confidential interval, for **Atlantic wolffish** for NEFOP data collection from May through December 2010. Eighteen gear/mesh and quarter combinations were evaluated; samples sizes are given by ASM and OB data set.

all 18 cells overlapped zero

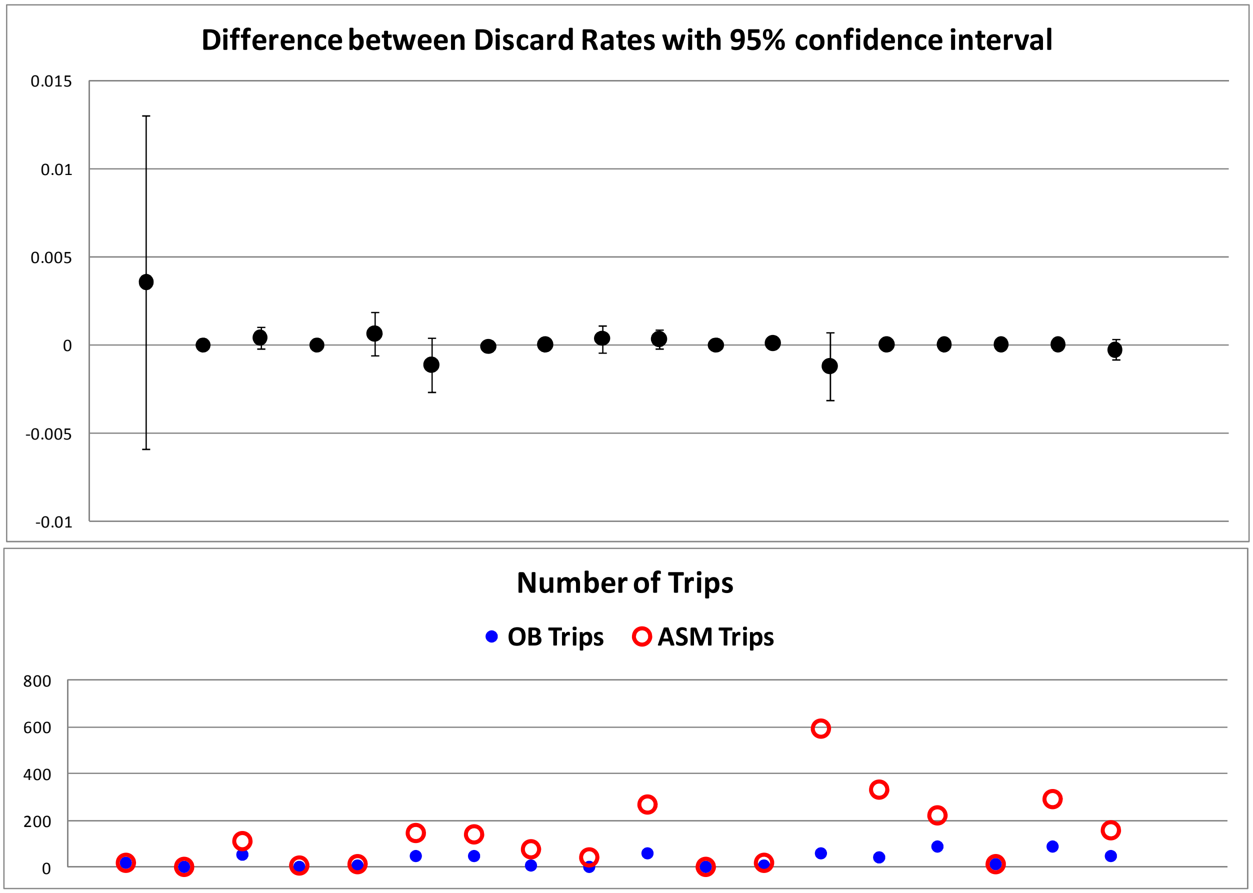
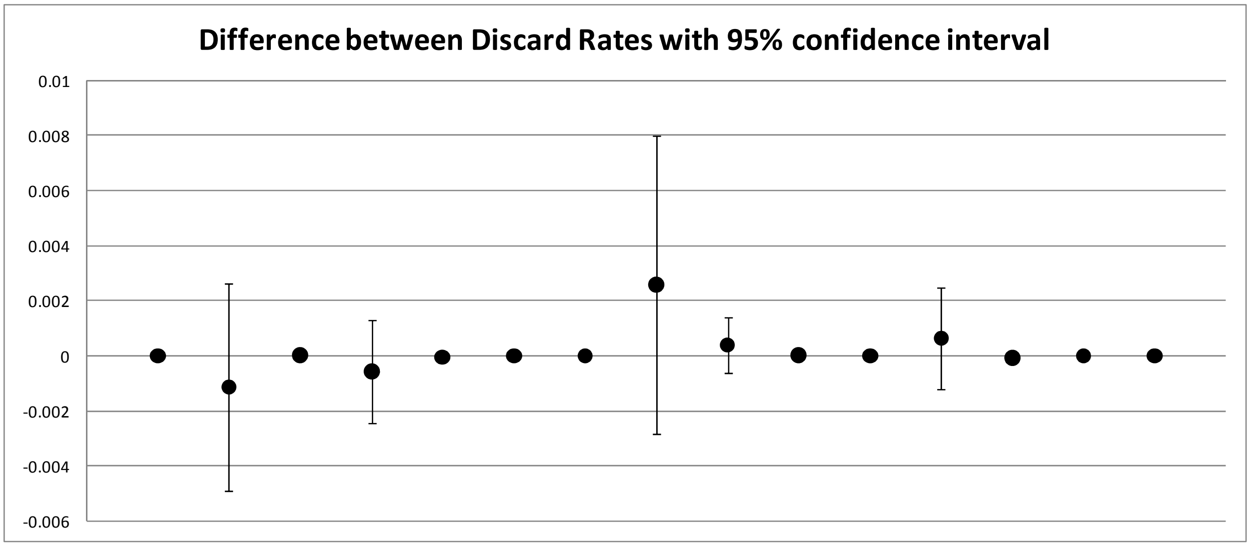


Figure 31. Difference between ASM and Observer discard rate, with 95% confidential interval, for **Gulf of Maine yellowtail flounder** for NEFOP data collection from May through December 2010. Fifteen gear/mesh and quarter combinations were evaluated; samples sizes are given by ASM and OB data set.

All 15 cells overlapped zero



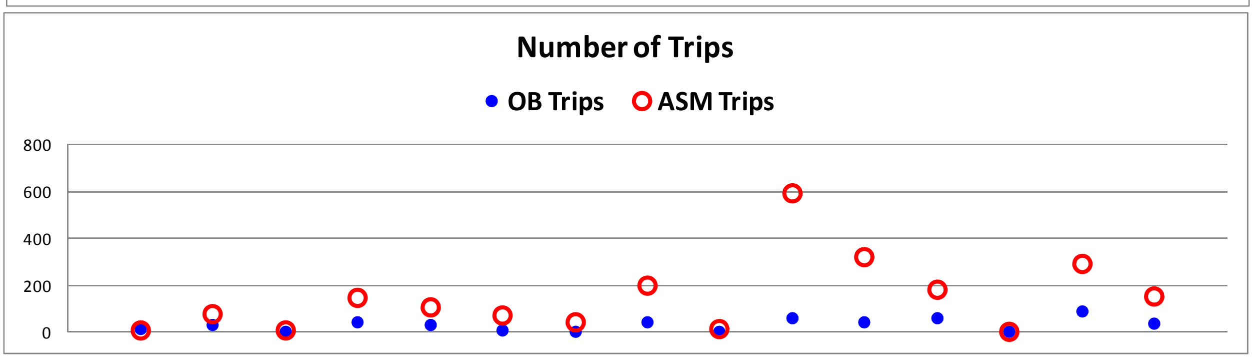


Figure 32. Difference between ASM and Observer discard rate, with 95% confidential interval, for **Georges Bank yellowtail flounder** for NEFOP data collection from May through December 2010. Nine gear/mesh and quarter combinations were evaluated; samples sizes are given by ASM and OB data set.

7 of 9 cells overlapped zero

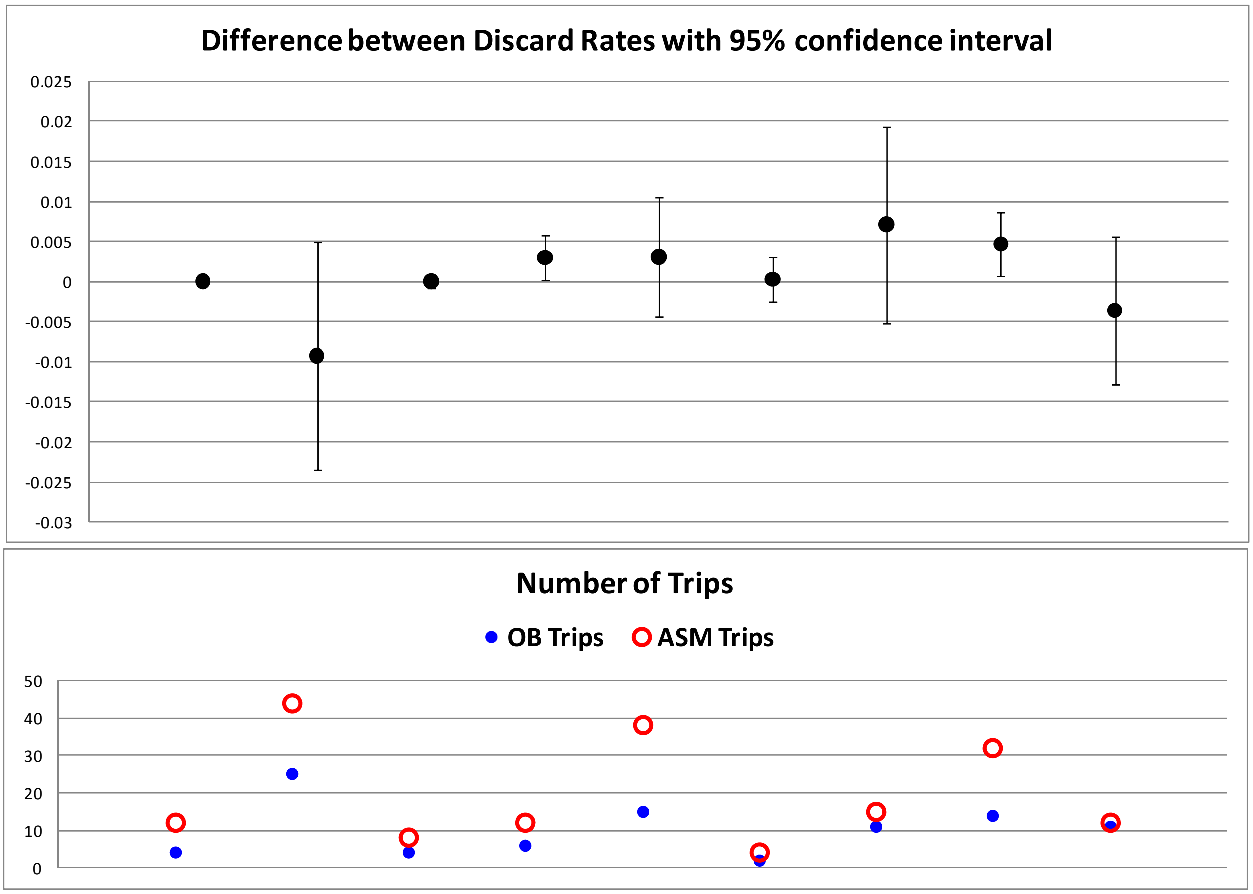
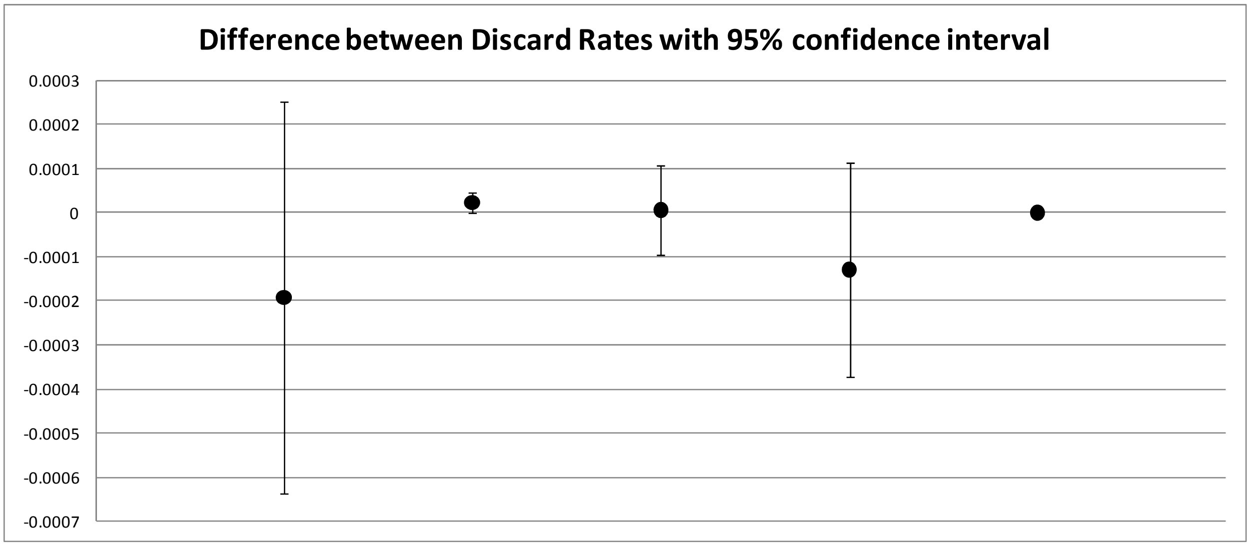
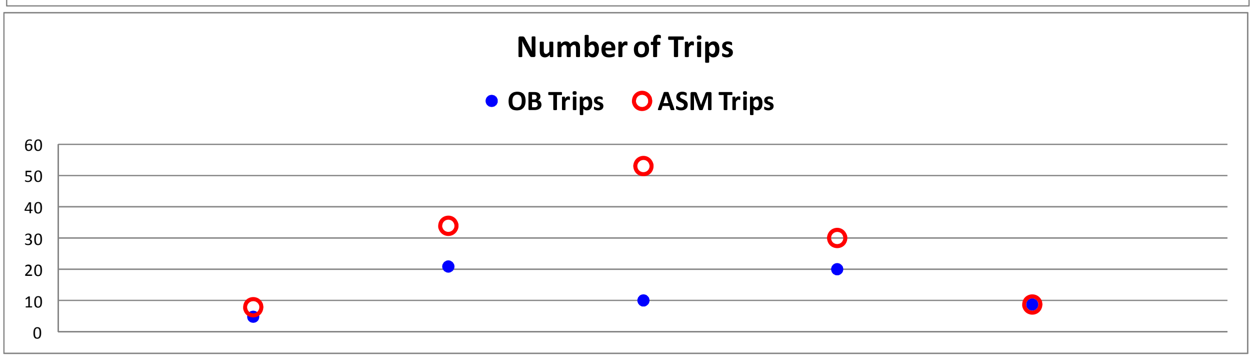


Figure 33. Difference between ASM and Observer discard rate, with 95% confidential interval, for **Southern New England yellowtail flounder** for NEFOP data collection from May through December 2010. Five gear/mesh and quarter combinations were evaluated; samples sizes are given by ASM and OB data set.

4 of 5 cells overlapped zero





SDWG Background WP#12
May 2011
Fish Repro Potential

Reproductive potential of female winter flounder, *Pseudopleuronectes americanus*: Comparison of fecundity and skipped spawning among three stocks

A working paper presented at SARC 52

April 2011

W. David McElroy, Yvonna K. Rowinski, Emilee K. Towle, Richard S. McBride, and Mark J. Wuenschel

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1.0 Introduction

Data on the reproductive potential of a species are useful for estimating egg production and improving stock-recruitment relationships; however, these data are limited for many species in the northwest Atlantic (reviewed in Tomkiewicz et al. 2003). Some studies have estimated potential annual fecundity in winter flounder, *Pseudopleuronectes americanus* (Saila 1961; Topp 1967; Kennedy and Steele 1971; NUSCO 1987; Buckley et al. 1991), but these investigations differed widely in methodologies, geographic locales, and years. Spawning frequency, another important measure of reproductive potential, has been found to be non-annual for some mature individuals in several species of marine fish (skipped spawning). Skipped spawning has been identified in winter flounder in several parts of its range (Burton and Idler 1984; Burton 1994; Wuenschel et al. 2009; McBride et al. 2010). The pathway for this interruption to the reproductive cycle can vary among species (reviewed in Rideout et al. 2005). Skipped spawning in winter flounder has been characterized as the 'resting' type where a clutch of oocytes is not developed in that year (Burton 1994; Rideout et al. 2005). Although some data on the reproduction of winter flounder exists; there remains a need for data on many reproductive traits over the geographic range of this species as well as for providing time series for these parameters. This working paper addresses this reproductive data need and establishes a method for long-term monitoring of mature winter flounder annual spawning rates and potential fecundity.

Autodiametric curves are a recent advancement for estimating fecundity from the relationship between oocyte diameter and oocyte density (number per gram) within the ovary(Kurita & Kjesbu 2008; Witthames et al. 2009). As oocyte diameter increases the packing density decreases in a curvilinear relationship. This curve can then be used to rapidly estimate oocyte density from oocyte diameters, and potential annual fecundity (PAF) is estimated as the product of oocyte density and gonad weight. These curves have been applied successfully to a number of species with determinate fecundity but not winter flounder (reviewed in Kurita & Kjesbu 2008; Witthames et al. 2009). In species with determinate fecundity, the total fecundity just prior to spawning is equivalent to the PAF for the year (Murua and Saborido-Rey 2003). The autodiametric method provides a rapid and easily standardized methodology for the estimation of fecundity, enabling fecundity estimation across a broad geographic scale and over multiple years. Time-series of fecundity estimates can be used to identify the importance of environmental (e.g. temperature) and biological (e.g. feeding) factors on the annual reproductive potential of fishes (Rideout and Morgan 2010). The autodiameteric method should be applicable to winter flounder, as this species exhibits group synchronous oocyte development and determinate fecundity (Murua and Saborido-Rey 2003).

The objective of this study was to evaluate the reproductive potential of winter flounder and some of the factors that influence it. This included examination of differences in reproductive potential among the three stocks of winter flounder in US waters: Gulf of Maine (GOM), Georges Bank (GB), and Mid-Atlantic-Southern New England (SNE). Reproductive potential was evaluated by estimating both potential annual fecundity and skip spawning rates.

2.0 Methods

2.1 Fish collection and processing

Data presented here are from an ongoing project (December 2009-present). Winter flounder were obtained on a monthly basis, and samples from December 2009 through February 2011 are included in this analysis. Fish were collected primarily by commercial fishing vessels in the Cooperative Research Study Fleet program. Some supplemental samples were acquired from field studies conducted by the

NEFSC Cooperative Research Program, Massachusetts Department of Fish and Game, Division of Marine Fisheries trawl survey, and the University of Rhode Island Jefferies trawl survey. Fish were requested from the last few tows of the last day of a fishing trip and were placed on ice to ensure the quality of the reproductive tissue. Approximately 30 fish were requested over the range of sizes captured on the last few tows, and therefore do not represent a random sample of the population or commercial catch. Fish were worked up immediately upon arrival at the lab. Fish length and mass, gonad mass, age samples, and other biological data were collected in the lab. A one cubic centimeter piece of tissue was excised from the middle of one of the ovarian lobes and fixed in 10% buffered formalin, and otoliths were removed for subsequent age determination by the NEFSC Fishery Biology Program (Penttila and Dery 1988).

2.2 Fecundity sample & image processing

Mature developing females with vitellogenic (yolked) oocytes were selected for fecundity analysis. The histology was evaluated to exclude females with signs of spawning activity, high levels of natural or post-mortem atresia or cell damage. Subsamples were taken from the fixed ovarian tissue avoiding the tunica tissue (gonad wall), patted dry, and weighed to the nearest 0.0001g. A sample of ~300-400 oocytes was targeted to balance the image quality with processing time. The subsamples were manually manipulated to separate the individual oocytes, which were then transferred to three small dishes to avoid crowding. Images were taken of each dish with a Leica MZ6 scope and DFC295 camera. ImageJ software (v. 1.44n, National Institute of Health) and the ObjectJ (v. 1.01i, University of Amsterdam) plugin were used for image processing. Treatment of images was made consistent between samples by use of a macro, modified from one developed for mackerel (provided by Dr. Anders Thorsen, Institute of Marine Research, Bergen, Norway). This macro automatically measured oocyte diameters, and subsequent inspection of the image allowed removal or remeasurement of erroneous values. Any damaged or warped oocytes were not utilized for diameter measurements, but these were still included in the total oocyte count used to determine the final number of oocytes per gram of ovarian tissue (# oocytes/g) in each subsample. All subsamples and images were evaluated on a qualitative scale (1-3), which were classified based on the clarity of images, amount of warped and damaged oocytes, and quantity of connective tissue clinging to oocytes. Poor samples (3) were excluded from analysis ($n = 91$), and additional subsamples were processed for those fish. The replicate weighed subsamples from individual fish were pooled for the analyses below.

2.3 Auto-diametric curves and statistical fitting

The resulting relationship between oocyte density (# oocytes/g) and oocyte diameter was described with both a power and exponential function, as regression models have varied among species in previous studies (Thorsen and Kjesbu 2001; Kennedy et al. 2007; Witthames et al. 2009). Regressions were fit by least squares regression using “R” (v. 2.12.1, R Foundation for Statistical Computing), and the most appropriate model was selected by comparison of Akaike’s Information Criterion (AIC). The model with the lowest AIC value was considered the most appropriate (Anderson 2008). The effect of stock as a factor in the autodiameteric relationship was tested on the natural log transformed data, with stock as a main effect as well as with an interaction term included.

2.4 Potential annual fecundity (PAF) estimation

The wet weight of the gonads includes the tunica, so an adjustment factor needed to be determined to not attribute tunica mass to that of oocytes. For a subsample of developing winter flounder ($n = 71$), a whole gonad was weighed and then stripped of all oocytes, and the remaining tunica tissue was weighed.

The mean percentage of the gonad mass that was tunica was 5.26 % (0.17 s.e.). The following relationship was used to calculate PAF for all fish:

$PAF = NG \cdot (GM \cdot 0.9474)$,

where NG is the number of vitellogenic oocytes per gram and GM the total gonad mass. Least-squares linear regressions were compared among stocks for natural log transformed PAF and gonad-free fish mass data, and transformed PAF data was also compared to the non-transformed age data. The regression models were compared using AICc values, as this measure is less influenced by low sample sizes (Anderson 2008). A base model with PAF results for all fish was compared to a model including stock as a main effect and a third model including an interaction term. The final accepted model was the one with lowest AICc value. As age and fish mass are related, regression analysis was also conducted between fish age and log-transformed gonad-free fish mass.

2.4 Histology processing & staging scheme

Fresh ovary tissue was fixed in 10% buffered formalin, cut to < 1 cm thickness, loaded in cassettes, and stored in 70% ethyl alcohol. These were then sent to an outside firm, Mass Histology Inc. Samples were dehydrated in a series of increasing ethyl alcohol concentrations before embedding in wax, and thin sections (5 µm) of embedded tissue were stained with Schiffs-Mallory trichrome (SMT) and mounted on microscope slides.

Histology slides were analyzed with a digital microscope (Nikon Coolscope II). Our protocol included recording the most advanced oocyte stage (MAOS), the presence and stage of postovulatory follicles (POF's) and atresia, presence of cysts, and tunica and stroma thickness. The MAOS was defined as primary growth (all oocyte stages prior to late cortical alveolar), early cortical alveolar, late cortical alveolar, early vitellogenic, late vitellogenic, germinal vesicle migration, nucleus breakdown one (hydrated oocyte inside the follicle), and nucleus breakdown two (hydrated oocyte outside the follicle).

2.5 Definition of criteria for skip spawning

Development of oocytes from primary growth to hydration takes approximately 1 year. As females reached the end of the spawning season in late spring and early summer and begin to prepare for the following season a cohort of oocytes enter into the cortical alveolar stage. For a majority of females, a cohort of oocytes advanced into vitellogenesis in the fall and winter, taking the next step towards spawning. Mature winter flounder can skip spawning, which is evident when a clutch of vitellogenic oocytes does not develop (Burton 1994; Rideout et al. 2005). A 'skipper' looks mature (thick tunica) but resting through the spawning period. Microscopically, the oocytes in these mature females remained in the primary growth or early cortical alveolar stage, and these fish also did not exhibit signs of spawning (POF's).

The months used to estimate skipped spawning were stock-specific, as the peak spawning period varies. These stock-specific periods were determined for each winter flounder stock based on two histological variables: MAOS and the occurrence of POFs. These patterns were also compared to monthly patterns in GSI. Skipped spawning should be best evaluated after the majority of the population had begun the physiological buildup for spawning (a substantial increase in GSI and the most advanced oocytes being vitellogenic). However, after the peak in spawning for each stock (determined based on the occurrence of numerous spent fish with low GSI's and lots of POF's) it became difficult to identify skipped spawners from those that spawned early. Based on these criteria skipped spawning was evaluated from the beginning of December until the end of April in SNE and GB stock areas, and from the beginning of January through the end of May in the GOM stock.

3.0 Results and Discussion

3.1 Autodiametric curves

A total of 236 fish that met the sample quality criteria were used to develop the oocyte diameter vs. oocyte density relationship (Appendix Figure 1). Examination of the histology for individuals with mean oocyte diameters < 500 µm, indicated more frequent occurrence of a low-level of atresia than for individuals with higher mean diameters. This may indicate down-regulation of fecundity; therefore subsequent analysis was constricted to only those fish with a mean oocyte diameter > 500 µm. Both the power and exponential functions fit the autodiametric data well, but lower AIC values indicated the power function was the more appropriate model for this species (Table 1) and was utilized in all subsequent analyses. Individual variation among fish appeared to be more important than stock for the autodiametric curves (Figure 1). As the individual variation was high and the truncated data set exhibited a less-curved nature, examination of the effect of stock on the autodiametric relationship was tested on the linear regressions of natural log-transformed data. The model with the lowest AIC value was the base model without stock as a factor (Table 2). Therefore, one autodiametric curve for all three populations can be used to estimate fecundity of winter flounder (n = 165),
$NG = 5.756 \cdot 10^{10} \cdot (OD)^{-2.442}$,
where NG is the number of oocytes per gram and the OD the mean oocyte diameter (µm). Overall the autodiametric method was found to be applicable to this species, and the resulting curve will facilitate future estimation of fecundity. This will include tracking interannual changes, as a time series of fecundity might help explain some of the variability in fecundity observed here (by exploration of the influence of environmental or physiological factors).

3.2 Potential annual fecundity

Estimates of potential annual fecundity for winter flounder were found to exhibit a strong relationship with increasing fish mass (Figure 2), as has been shown in other fishes (Lowerre-Barbieri 2009; Rideout and Morgan 2010). Some of the variation in PAF estimates was explained by stock, which as a main effect was found to improve regression models of fish mass and PAF (Table 3). The inclusion of an interaction term did not lower the AICc value so was not considered an improvement in the model. The SNE stock was found to have the highest production of eggs relative to fish mass and the GOM stock had the lowest (Figure 2). The GB stock had the heaviest fish of the three stocks, so produced the greatest total number of eggs per individual. Although, analysis of PAF was conducted on gonad-free fish mass; final stock specific regressions for PAF in relation to fish mass were determined for both gonad-free and total fish mass (Table 4).

Observed ranges of fish mass were not consistent among stock areas, particularly GB (Figure 2); so comparisons of the fish mass to PAF relationship were also made across masses common to the stock areas (Appendix Table 1). Overlapping mass ranges were compared between GOM and SNE, SNE and GB, and all three stock areas. Although, the sample sizes were quite low in some cases, the same results were found for all comparisons in that the main effect of stock always had the lowest AICc values with a substantial improvement over the base model of PAF and gonad-free fish mass. Inclusion of the interaction term consistently had a lower value than the base model, but not from the model with the main effect alone.

All the statistical comparisons of PAF estimates indicated distinct differences among the three stock areas, with SNE exhibiting the greatest number of eggs produced relative to body mass. Fish mass was found to have a strong relationship with egg numbers, evidenced by the highest fecundities in the GB stock that has faster growth and attains greater sizes than the other stocks. Fecundity results in the present study are within the range but higher than most estimates previously reported for this species (Table 5). There is considerable variation, however, among studies even within the same region. Comparison of specific values among studies is confounded by many factors, including temporal and geographic variation and differences in methodology. In the current study, the utilization of one method, as well as being within the one time period, enables comparison across a broad geographic region. This includes the first estimates of fecundity for Georges Bank.

Fish size and age are closely related, and differences among stocks were also clearly evident in comparisons of fish mass (gonad-free) at age (Figure 3a). Georges Bank consistently had heavier fish at age than the SNE stock, and especially relative to the GOM stock. Potential annual fecundity at age exhibited a similar pattern of gradually increasing with age in all three stock areas (Figure 3b). The differences in PAF at age among the stock areas reflected the differences in size at age, with GB having the highest values and GOM the lowest. However, the differences in PAF at age estimates between GB and SNE fish were not as strong as the differences were in size at age. Regression models of PAF with age again showed an improvement with the inclusion of stock as a main effect, though only slightly over the model with the interaction term (Table 3b). Results of the age analysis were consistent with those for fish size. When adjusted for fish size, SNE winter flounder produced the greatest number of eggs and GOM fish produced the fewest. The differences in size at age of the GB fish resulted in greater egg production by the older (larger) individuals of that population, and the smaller size of the GOM fish resulted in lower egg production at age for that population.

Results here support the idea that female size is the most important factor for egg production, which is consistent with work on many species (Lowerre-Barbieri 2009). These fecundity results emphasize the importance of larger fish to the population, even when their numbers may be a much less significant portion of the total population. These results, however, are just for total egg numbers and do not include egg quality or size, which can also vary with female size and have consequences for the size and survival of larvae (Buckley et al. 1991; Tomkiewicz et al. 2003; Lowerre-Barbieri 2009; Rideout and Morgan 2010).

3.3 Skipped spawning

The processing and examination of gonad histology slides for female winter flounder from the 2010 spawning season has been completed. A total of 332 mature females were examined in all three stock areas during the five month periods analyzed. Sample sizes for the GOM and SNE stocks were similar, with fewer fish collected from the GB stock (Table 6). Only two individuals were identified as skipped spawners for the 2010 spawning season, both of which came from the Gulf of Maine. This was 1.3 % of the sampled adult female winter flounder from the GOM stock (Table 6). The prevalence of skipped spawning for the US winter flounder stocks in 2010 was below that of winter flounder sampled in Newfoundland, 19.1% (9 of 47 mature females examined; Burton and Idler 1984), but closer to that reported for winter flounder in New Jersey, 4.8 % (3 of 63 mature females; Wuenschel et al. 2009). Burton and Idler (1984) also identified skipped spawning in 18 of 63 (28.6 %) mature males. A latitudinal gradient in the frequency of non-annual spawning may be exist. This was suggested in preliminary results of a histological examination of winter flounder from the US Mid-Atlantic bight up to the Scotian Shelf (McBride et al. 2010), which ranged from zero to greater than 30%.

Skipping rates can vary substantially among years as a suite of environmental and physiological factors could impact spawning participation (Rideout et al. 2005). Although, the overall incidence of skipped spawning observed in this study was low, captive studies suggest that feeding during a critical period after spawning influenced whether individuals were non-reproductive the following season (Burton 1994). This suggests that interannual variation in the environment could have a substantial role in the frequency of occurrence of skipped spawning, and in years of high incidence (~10-20%) this could significantly decrease the realized spawning biomass of the population. Inclusion of skipped spawning rates in population models may improve estimates of spawning stock biomass and their relationship to recruitment. Egg production models incorporating stock-specific differences in fecundity and female size could also provide insight into year to year variation in the stock recruitment relationship.

4.0 Conclusions

This work provides reproductive parameters for potential annual fecundity (2010-2011) and skipped spawning (2010) for the three US stocks of winter flounder. This study developed autodiametric curves for winter flounder, which enables rapid estimation of fecundity in the future by utilizing just the mean oocyte diameter for an individual fish to determine oocyte density. This will facilitate our ability to track longterm changes in this reproductive parameter, as well as investigate the effects of factors influencing egg production in the wild, such as temperature, fish condition, and food availability. Monthly sampling enabled identification of, and resulting analysis during, the optimal months for evaluating reproductive parameters for each particular stock.

The overall reproductive potential for individuals in the Gulf of Maine stock of winter flounder were the lowest of the three US stocks, as both fecundity and skipped spawning suggest lower reproductive output for fish in this population. This is consistent with the growth rate for this stock, which is slower than the other two (O'Brien et al. 1993). Preliminary results suggest geographic differences in fecundity on a smaller scale than stock may exist, especially for the Gulf of Maine, and future work is under way to examine this possibility further. The two southern stocks appear to have lower rates of skipped spawning, as well as higher egg production per fish than GOM, both in relation to fish mass and age. SNE fish have the greatest individual egg production in relation to body mass, but the larger mass attained by Georges Bank flounder results in a higher reproductive capacity for the large individuals in this stock. These results indicate that the reproductive potential of the stocks could differ and may provide indicators of the resiliency of the different populations to fishing pressure.

5.0 Acknowledgements

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7.0 Tables

Table 1. Coefficients and statistics for the power and exponential models as fit with least squares regression of oocyte density (# / g ovarian tissue) and mean oocyte diameter (Mean OD) are tabulated along with residual sums of squares (RSS) and the Akaike’s Information Criterion (AIC). Analysis conducted with all winter flounder stocks combined and only on females with mean oocyte diameters > 500 μm.

Oocyte Density =	d.f.	a	b	RSS	AIC	ΔAIC
$a \cdot (\text{Mean OD})^b$	163	$5.756 \cdot 10^{10}$	-2.442	$1.359 \cdot 10^8$	2721.804	
$a \cdot e^{(\text{Mean OD} \cdot b)}$	163	$1.222 \cdot 10^5$	$-4.255 \cdot 10^{-3}$	$1.379 \cdot 10^8$	2724.208	2.404

Table 2. Comparison of autodiametric relationships between stocks were conducted only on fecundity samples with oocyte diameters > 500 μm. Data were natural log transformed, and models of the linear regression of the oocyte density and mean oocyte diameters were compared using AICc values and weights (Wt). The first model was without stock as a factor (base model), the second with stock as a main effect, and the third with the interaction term.

	K	AICc	ΔAICc	AICc Wt.
1 Base Model	3	-346.18		0.50
2 Main effect of stock	5	-345.75	0.42	0.40
3 Model w/Interaction Term	7	-342.97	3.21	0.10

Table 3. Natural log transformed potential annual fecundity (PAF) data was regressed with log-transformed gonad-free fish mass (a) and non-transformed fish age (b), and the model was tested with and without stock as a factor. Base model is without stock, the second model is with stock as a main effect, and the third is the model with the interaction term included. The forms of the model were compared using AICc values and weights (Wt).

a	K	AICc	ΔAICc	AICc Wt.
1 Base Model	3	6.42	22.26	0.00
2 Main effect of stock	5	-15.84		0.67
3 Model w/Interaction Term	7	-14.40	1.44	0.33

b	K	AICc	ΔAICc	AICc Wt.
1 Base Model	3	266.15	163.22	0.00
2 Main effect of stock	5	102.52		0.78
3 Model w/Interaction Term	7	105.52	2.59	0.22

Table 4. Final regression coefficients for the relationship between fish mass and potential annual fecundity (PAF) for each stock area, LN(PAF) = b · LN(Mass) + a, where mass is either gonad-free or total fish mass.

Gonad-Free	a	b	n
GOM	7.726	0.959	45
GB	6.626	1.150	47
SNE	6.860	1.138	72

Total Mass	a	b	n
GOM	7.213	1.016	45
GB	6.974	1.069	47
SNE	6.520	1.152	72

Table 5. Predicted PAF estimates are based on regressions from previous studies and stock specific regressions from the current study based on whole fish mass. The 500g and 1000g estimates were not determined for the GB and GOM stock areas, respectively; since in the current study fish those sizes were not encountered from those regions. The 1000g size was not estimated for the two more northern studies as this size would not be typically encountered in those regions.

		Total Fish Mass (g)		
	Location	500	800	1000
Current Study	GOM	747,676	1,205,057	
	GB		1,353,164	1,717,619
	SNE	870,343	1,495,392	1,933,555
Saila (1961)	Narragansett Bay	554,134	946,065	1,219,586
Topp (1967)	Cape Cod Bay	884,163	1,459,162	
Kennedy & Steele (1971)	Newfoundland	545,673	977,468	
NUSCO (1987)	Long Island Sound	650,271	1,295,795	1,797,637
Buckley et al. (1991)	Narragansett Bay	624,720	1,043,820	1,323,220

Table 6. Total number of mature female winter flounder examined by histology in each stock area in winter 2009-2010, and the number of mature non-spawning participant females (skipped spawners) within each stock area. Skipped spawning identification period was defined for Southern New England (SNE) and Georges Bank (GB) stock areas to be from December through the end of April, and January until the end of May for the Gulf of Maine (GOM) stock.

Stock	Mature Females	Skipped Spawners	% Skipped
GOM	151	2	1.32
GB	35	0	0.00
SNE	146	0	0.00

8.0 Figures

Figure 1. Relationship between oocyte density (number per gram) and mean oocyte diameter (autodiametric curves) for the three stocks of winter flounder. Individuals with mean diameters < 500 µm were excluded from analysis. Curves represent least-squares fit regressions for the power function.

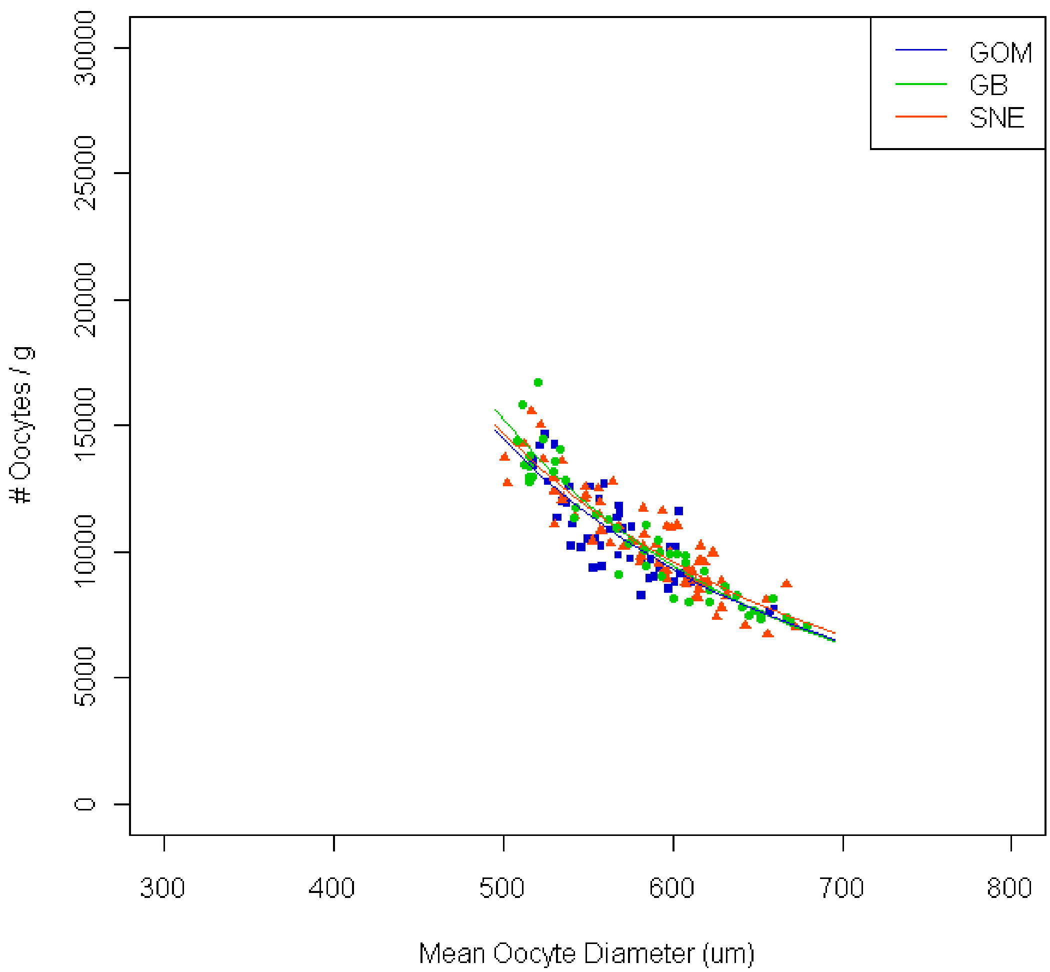


Figure 2. Comparison of gonad-free fish mass and potential annual fecundity plotted on a log-log scale for each stock of winter flounder. Lines are least-squares fit of the linear regressions of each stock over the size range sampled.

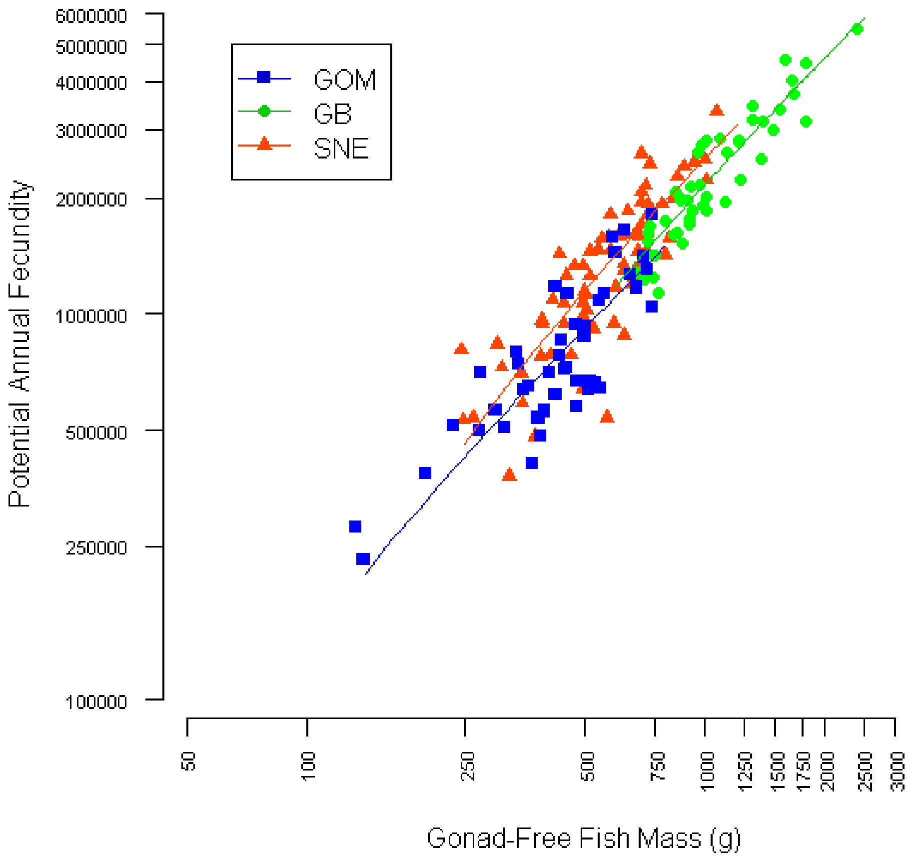
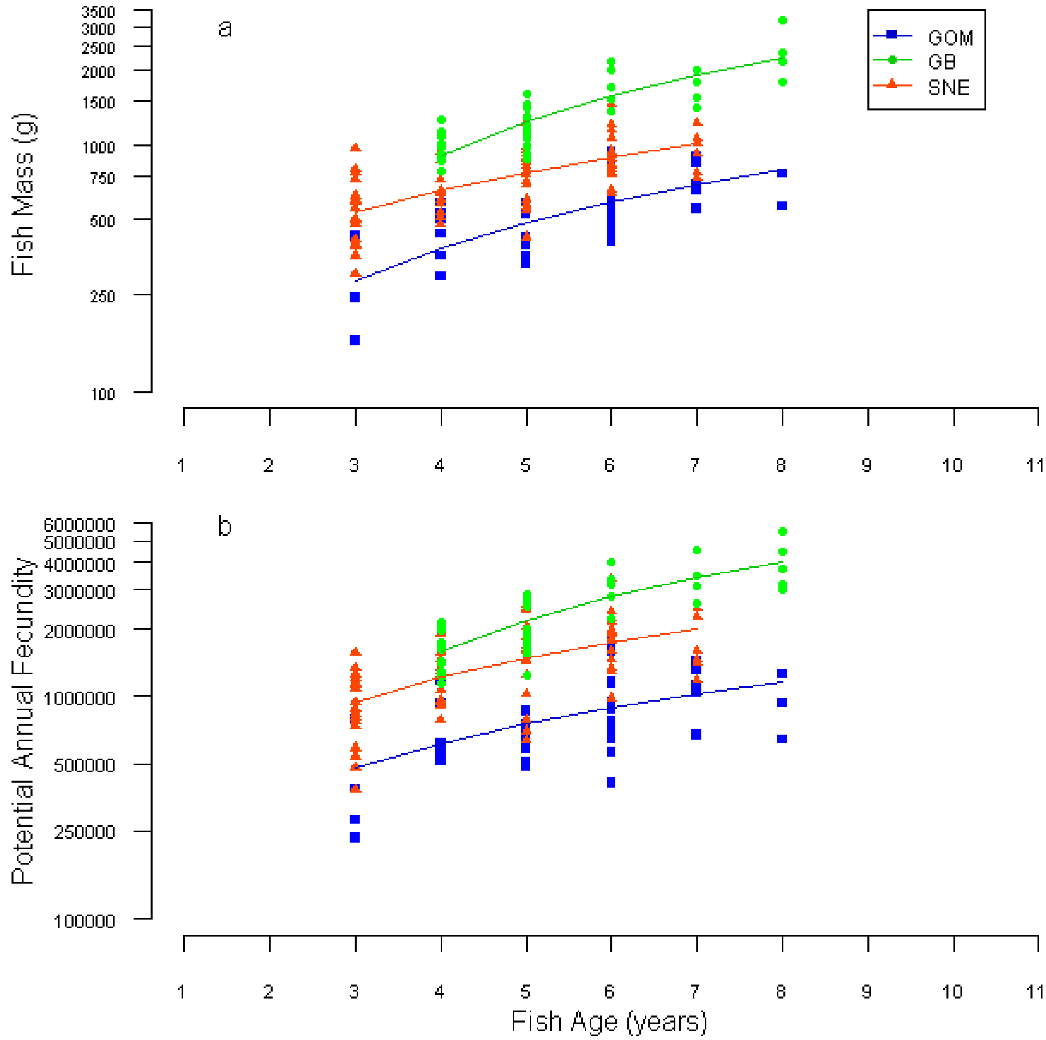
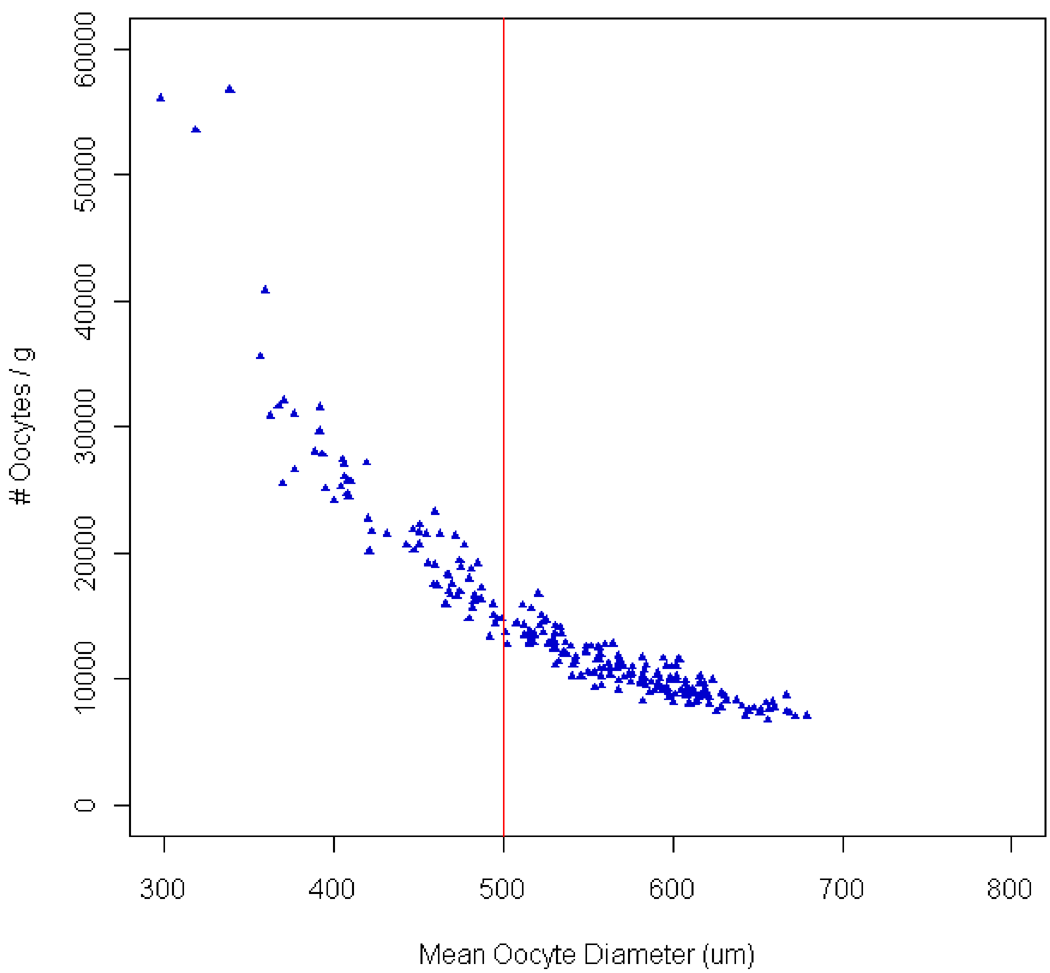


Figure 3. Winter flounder mass (on a log scale) plotted in relation to age by stock (a). Potential annual fecundity plotted on a log scale against fish age for each winter flounder stock (b). Lines are least-squares fit of the linear regressions of each stock over the size range sampled.



Appendix

Appendix Figure 1. Relationship between oocyte density (number per gram) and mean oocyte diameter for all winter flounder sampled for fecundity and meeting sample quality criteria. Verticle line at 500 µm indicates oocyte diameter cutoff employed for analysis; as histology slides indicated greater occurrence of atresia below that size.



Appendix Table 1. Natural log transformed potential annual fecundity (PAF) data was regressed with log-transformed gonad-free fish mass, and the model was tested with and without stock as a factor for each grouping below. Base model is without stock, the second model is with stock as a main effect, and the third is the model with the interaction term included. The forms of the model were compared using AICc values and weights (Wt). Potential annual fecundity comparisons among stocks were restricted to fish sizes overlapping in value between the stocks. Two stock comparisons were made for winter flounder from SNE < 740g (n = 62) with GOM flounder > 230g (n = 42, a), as well as SNE flounder > 675g (n = 23) and GB flounder < 1070g (n = 29, b). The comparison of regressions between all three stocks was constricted to flounder in GOM > 675g (n = 5), GB < 740g (n = 7), and SNE between 675-740g (n = 13, c).

a	K	AICc	ΔAICc	AICc Wt.
1 Base Model	3	37.19	16.42	0.00
2 Main effect of stock	4	20.77		0.68
3 Model w/Interaction Term	5	22.31	1.54	0.32

b	K	AICc	ΔAICc	AICc Wt.
1 Base Model	3	-19.32	13.85	0.00
2 Main effect of stock	4	-33.17		0.60
3 Model w/Interaction Term	5	-32.33	0.84	0.40

c	K	AICc	ΔAICc	AICc Wt.
1 Base Model	3	3.63	8.10	0.02
2 Main effect of stock	5	-4.47		0.95
3 Model w/Interaction Term	7	2.56	7.03	0.03

ToR 5. Examine the effects of incorporating environmental factors in models of population dynamics (e.g., spring water temperatures in an environmentally-explicit stock recruitment function).

Development of environmentally-explicit stock-recruitment models for three stocks of winter flounder (*Pseudopleuronectes americanus*) along the northeast coast of the United States

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Introduction

Winter flounder spawn in winter and early spring in estuaries along the mid-Atlantic, southern New England and Gulf of Maine, as well as in continental shelf waters on Georges Bank (Able and Fahay 2010). There is also recent evidence of more coastal spawning in both Southern New England (Wuenschel et al. 2009) and the Gulf of Maine (Fairchild et al. 2010). In southern New England, Manderson (2008) found that overall recruitment was linked to spring temperatures, presumably by acting on larvae, settlement stage, and/or early juveniles. Further, Manderson (2008) found that young-of-the-abundance among 19 coastal nurseries became more synchorized in the early 1990's and argued that increased frequency of warm springs was creating coherence in early life stage dynamics among local populations.

The specific mechanism linking temperature to recruitment was not defined by Manderson (2008), but temperature is an important parameter in many ecological processes affecting winter flounder. In a mesocosm study, Keller and Klein-MacPhee (2000) found that winter flounder egg survival, percent hatch, time to hatch, and initial size were significantly greater in cool mesocosms. Further, mortality rates were lower in cool mesocosms and related to the abundance of active predators. In the laboratory, Taylor and Collie (2003) found that consumption rates of sand shrimp were lower at lower temperatures implying lower predation pressure at colder temperatures. In the field, Stoner et al. (2001) found that settlement stage winter flounder prefer colder waters and that the importance of temperature in defining juvenile habitat decreases through ontogeny. Thus, temperature has multiple effects on the early life history of winter flounder and colder temperatures in general lead to higher survival and recruitment.

The relationship between winter flounder recruitment and temperature identified by Manderson (2008) did not include the effect of population size. The relationship between stock size and subsequent recruitment is generally poor in marine fishes (Rothschild 1986) but can have explanatory power. To examine the combined effect of environment and spawning stock biomass on recruitment, the goal here was to develop environmentally-explicit stock recruitment relationships that include temperature and related environmental variables for the three stocks of winter flounder. As a basic framework, the approach of Hare et al. (2010) was followed. The resulting models could be used in short-term forecasts based on fishing and temperature scenarios (fixed patterns of temperature variability over several years) and long-term forecasts based on fishing and temperature projections from general circulation models.

Materials and Methods

Data

To develop environmentally-explicit stock recruitment relationships, three specific types of data are required: spawning stock biomass, recruitment, and environmental data.

Spawning stock biomass and recruitment data – Results from the preferred assessment models were used in the analysis. For the Southern New England stock, recruitment (lagged by 1 year) and spawning stock biomass pairs used from the CAT10 ASAP model. For the Gulf of Maine stock, data from the MULTI ASAP model were used. For the Georges Bank stock, data from the preferred VPA model were used (Table 1).

Environmental Data - Temperature – Two general types of temperature data were used: air temperatures and coastal water temperatures. Data sources are provided in Table 2.

Air temperature data from the NCEP/NCAR Reanalysis (Kalnay et al. 1996) were used. This product combines observations and an atmospheric model to produce an even grid of atmospheric variables, in our case monthly mean surface air temperature. The spatial resolution is 2.5^{o} latitude by 2.5^{o} longitude. Air temperatures are closely related to estuarine water temperatures owing to efficient heat exchange in the shallow systems (Roelofs and Bumpus 1953, Hettler and Chester 1982, Hare and Able 2007). Data from representative grid points were averaged for each of three regions: Southern New England, Georges Bank, and Southern New England (see Figure 1). The monthly/regional averages were further averaged into annual estimates for three, two monthly periods (January-February, March-April, May-June).

Coastal water temperature data from Woods Hole, Massachusetts and Boothbay Harbor, Maine were used (see Nixon et al. 2004 and Lazzari 1997 respectively). Monthly means were calculated from mostly daily data. These monthly means were then averaged into annual estimates for the three, two monthly periods (January-February, March-April, May-June). The Woods Hole data were evaluated relative to the Southern New England and Georges Bank stock; the Boothbay Harbor data were evaluated relative to the Gulf of Maine stock.

Temperature data were analyzed as annual averages for three, two month periods (January-February, March-April, May-June). These two monthly periods capture temperature variability from the late winter, through spring and into early summer. The spring period was identified as important by Manderson (2008). The broader seasonal range was chosen because of potential differences in the timing of winter flounder spawning and development among the three stocks (Able and Fahay 2010) and the uncertainty as to the stage where recruitment is determined.

Environmental Data - Large-scale forcing variables – In addition to temperature, four large-scale forcing indices were included in the analyses (see Table 2). The North Atlantic Oscillation (NAO) is the dominant mode of winter climate variability in the North Atlantic region and has been related to numerous physical and biological variables across the North Atlantic (Ottersen et al. 2001, Visbeck et al. 2003). Brodziak and O'Brien (2005) identified a significant effect of NAO on recruit-spawner anomalies of winter flounder in the Gulf of Maine. The mechanism is unspecified, but NAO is related to estuarine water temperatures in the region (Hare and Able 2007). The winter NAO index is used here (Hurrell and Deser 2010). The Atlantic Multidecadal Oscillation (AMO) is a natural mode of climate variability and represents a detrended multi-decadal pattern of sea surface temperatures across the North Atlantic with a period of 60-80 years (Kerr 2005). Nye et al. (2009) found the AMO was strongly related to distribution shifts of fishes in the northeast U.S. shelf ecosystem. Finally, the Gulf Stream index is a measure of the northern extent of the Gulf Stream south of the northeast U.S. shelf ecosystem. The Gulf Stream position is related to the larger basin-wide circulation, which in turn is related to NAO and AMO. Work by Nye et al (in review) shows the Gulf Stream index has explanatory power for the distribution of silver hake in the system, possibly through the large-scale linkages between the Gulf Stream, Labrador Current and hydrographic conditions on the northeast U.S. shelf. Two Gulf Stream indices are used here (Joyce and Zhang 2010, Taylor and Stephens 1998). The two indices differ in their calculation, with the Joyce and Zhang (2010) index more associated with the Gulf Stream south of the northeast U.S. shelf and the Taylor and Stephens (1998) index more associated with the Gulf Stream across the North Atlantic.

For all four large-scale forcing indices, annual values were obtained. Numerous studies have found lagged effects of the NAO on the northeast U.S. shelf ecosystem (Greene et al. 2003, Hare and Kane in press). In particular, a two year lag has been related to the remote forcing of the NAO on the northeast U.S. shelf through the Labrador Current system. In addition, a zero year lag has been related to direct atmospheric forcing on the northeast U.S. shelf. Zero, one, and two year lags of were included for NAO and zero year lags were used for the other three large-scale forcing variables.

Preliminary Analysis of Environmental Data

To understand the relations between the host of 21 environmental variables, a simple correlation matrix was calculated. Significant correlations were considered in the context of previous research in the region. Significance was based on standard p-values; no corrections for multiple comparisons were made. The purpose was exploratory with an aim of understanding the relation between variables before incorporating them into stock recruitment functions.

Environmentally-Explicit Stock-Recruit Models

Initially, Ricker, Beverton-Holt, and Cushing stock recruitment models were used with and without the different environmental terms. The model forms followed Levi et al. (2003), who built upon the ideas of Neill et al. (1994) and Iles and Beverton (1998). The fits of the three standard models were all very similar for the Southern New England and Gulf of Maine stocks. Owing to the general acceptance of the Beverton-Holt model for use in stock-recruitment relationships and the overall similarity in the fits of the three models, here only the analyses using the Beverton-Holt model are presented (see Table 3 for model forms).

Environmental variables were assigned *a priori* for consideration with specific stocks (e.g., air temperatures over the Gulf of Maine were examined for the Gulf of Maine stock only, see Table 2). This was done to limit the number of environmentally-explicit stock recruitment relationships considered for each stock (see Table 2).

The standard stock-recruitment relationships were calculated first using the lsqcurvefit function in MatLab using the trust-region-reflective algorithm. A series of environmentally-explicit models also were fit using the same methods (Table 3). The resulting models were compared using AICc and AICc weights, which represent the relative weight of evidence in favor of a model. The best environmentally-explicit model also was compared to the standard stock recruitment model using an evidence of weights procedure (Burnham and Anderson 1998). In this way the value of the environmentally-explicit stock recruitment functions relative to standard stock recruitment functions was judged.

Model fitting included bounded parameters (or priors) to force realistic model forms. Without bounded parameters the b term in the Beverton-Holt model (see Table 3) was estimated to be negative for the Georges Bank stock, which results in an unrealistic function. To deal with this issue, starting values for the nonlinear estimation were derived from the linearized standard Beverton-Holt function and bounds of ± two orders of magnitude were imposed. The fit of the models for the Georges Bank and Southern New England data were much less sensitive to the bounds.

Results

Preliminary Analysis of Environmental Data

Numerous relationships between environmental variables were evident based on the correlation analysis. The complete correlation matrix is presented in Table 4 and representative time series are shown in Figure 2.

The two Gulf Stream indices were related (r=0.54) but different enough to retain both in the analyses. Both Gulf Stream indices were related to the NAO with a 2 year lag (NAO leading). This relationship has been described before (Taylor and Stephens 1998).

The Atlantic Multidecadal Oscillation exhibited relatively little relationship with other variables. There was a negative relationship with the 2 year lagged NAO. The only strong positive correlation was found with Boothbay Harbor water temperatures. Both series exhibit a strong increasing trend over the time period considered (Figure 2).

The North Atlantic Oscillation was related to the two Gulf Stream indices as already noted. NAO was not related to winter temperatures which may result from non-stationarity in the NAO-winter temperature relationship (Joyce 2002).

Woods Hole temperature is closely related to regional air temperatures. This link is not surprising based on previous studies. Woods Hole temperature is also related to a lesser extent Boothbay Harbor temperatures. There is evidence of seasonal correlation in Woods Hole temperature, with values in January and February correlated to values in March and April, which in turn are correlated to values in May and June. However, the seasonal correlation is diminished after two months; temperatures in January and February are less related to temperatures in May and June.

Boothbay Harbor temperature is strongly related to the AMO particularly in early summer. The lower magnitude of correlation with air temperatures compared to Woods Hole temperature is interesting and an explanation is lacking. It is possible that greater depths of coastal Maine increase the influence of oceanic factors and decreases the influence of atmospheric factors. The seasonal correlation described for Woods Hole temperatures in evident for Boothbay Harbor temperatures, but to a lesser degree.

The three air temperature series were all closely related indicating coherent air temperatures over the entire region. These analyses agree with the more comprehensive results of Joyce (2002). Correlations among regions over the same time (Jan-Feb) were higher than correlations within region between times (Gulf of Maine Jan-Feb compared to Gulf of Maine Mar-Apr). Seasonal correlation (Jan-Feb to Mar-Apr) were lower in the air temperature series compared to the water temperatures series as expected from the greater specific heat capacity of water.

The analyses suggest that the environmental forcing experienced by the three stocks differs in several important elements. The Southern New England stock experiences coastal water temperatures that are strongly linked to local air temperatures. The Georges Bank stock experiences water temperatures that are affected by both local air temperatures and more importantly, large-scale advective supply of relative cold, fresh water associated with the Labrador Current. Finally, the temperatures experienced by the Gulf of Maine stock remain uncertain. If the Boothbay Harbor data is representative, then temperature is related to large-scale processes (AMO) and not local processes (air temperature). On the other hand, air temperature may be important, if early stage winter flounder are using shallower habitats.

Standard Stock-Recruitment Models

Spawning stock biomass is comparable between the Southern New England and Georges Bank stock but recruitment is approximately four times greater for the Southern New England stock at higher stock sizes (Figure 3). The stock recruitment functions for the Georges Bank and Gulf of Maine stock are similar, with near constant recruitment over a relatively broad range of spawning stock biomasses. Recruitment on Georges Bank is estimated to be higher than the Gulf of Maine at a given spawning stock biomass.

The residuals of the stock-recruitment relationships for the three stocks appear to exhibit synchrony through time (Figure 4). Early in the time series, residuals between the stocks appear unrelated, but all residuals were positive in the mid-1990’s and all were negative in the early 2000’s. A formal analysis was conducted using serial correlation: calculating the correlation coefficient between two variables using a moving window. A similar analysis was used by Joyce (2002) to show that the relationship between NAO and east coast air temperatures has changed over the last 80 years and by Hare and Kane (in press) to show that the correlation between NAO and *Calanus finmarchicus* abundance has changed over the last twenty years. The serial correlation analysis demonstrated that early in the time series the residuals of the stock-recruitment functions were negatively or not correlated between the stocks (Figure 5). Then, during the early 1990's, the residuals became positively correlated. The trend is most evident for the Southern New England and Gulf of Maine stocks and less so for these two stocks compared to the Georges Bank stock.

The timing in the synchrony between the Southern New England and Gulf of Maine stocks is similar to the timing in synchrony among local populations within the Southern New England stock (Manderson 2008). This synchrony suggests that some large-scale forcing is responsible for creating variance in the stock recruitment relationships of winter flounder across the northeast U.S. shelf ecosystem. The synchrony is greater between the Southern New England and Gulf of Maine stocks suggesting that the large-scale forcing has greater coherence along the coastal areas of the northeast compared to the offshore waters of Georges Bank.

Environmentally-Explicit Stock Recruitment Models

The best fit environmentally-explicit stock recruitment relationship for the Southern New England stock predicted higher recruitment at lower winter air temperatures (Table 5, Figure 6). The variable in the best model was Southern New England air temperature in January and February. This model had an evidence ratio of 151 compared to the standard model and explained an additional 14% of the variance (Table 6). Several other environmental variables were included in the top ten models (AMO, GS-J, and WH-JF), but three of the four top models included winter air temperatures over Southern New England. The best environmentally-model provided a similar function to the standard model at mean environmental conditions, but importantly the predicted asymptotic recruitment was lower with the environmental model (Figure 6).

Including an environmental term did not improve the stock recruitment relationship for the Georges Bank stock (Table 6). The standard model was the best fit model and predicted near constant recruitment over the range of observations (Figure 7). The evidence ratio of the best environmental model was 0.7 compared to the standard model (Table 6). Environmental variables in the top 10 models included air temperatures, water temperatures and the Gulf Stream index, but these variables added no strength to the stock recruitment relationship (Table 5). Importantly, the model fit, whether standard or environmental, was dependent on the priors imposed for the b term (Table 3), which is related to but not identical to the steepness term (see Myers et al. 1999).

For the Gulf of Maine stock, the best model included winter air temperature over the Gulf of Maine (Table 5); at higher temperatures, there was a decrease in recruitment (Figure 8). Air temperatures through the spring and Boothbay Harbor winter temperatures were also included in the top 10 models. The best fit environmentally-explicit model has an evidence ratio of 2 compared to the best fit standard stock recruitment model and explained an additional 14% variance (Table 6).

The environmentally-explicit models support the hypothesis that increased temperatures during spawning and the early life history result in decreased recruitment in the Southern New England and Gulf of Maine stocks. This pattern was most evident for the Southern New England stock. Winter temperature is correlated with spring temperature (Table 3) providing a potential bridge between this study and that of Manderson (2007). For the Gulf of Maine stock, increased winter air temperatures are related to lower recruitment, but the strength of this environmental forcing is less than for Southern New England. This result makes sense in the context of the distribution of winter flounder; the southern stock is most affected by warmer temperatures. There was no evidence for a temperature effect on the Georges Bank stock; the environmentally-explicit models did not provide a better fit compared to the standard stock recruitment model. Overall, recruitment in the coastal stocks of winter flounder were linked to winter temperatures, while recruitment in the Georges Bank stock was largely independent of the environmental variables examined here.

Using the same serial correlation approach to examine trends in winter air temperature shows an increase in correlation among the three regions starting in the late-1980's early-1990's (Figure 9). The correlation coefficients of Southern New England and Gulf of Maine air temperatures are correlated with the similar coefficients for recruitment (Figure 9, see Figure 5) This result suggests that as regional air temperatures have become more coherent, winter flounder recruitment in the coastal stocks also has become more coherent.

<u>Summary of Stock Recruitment Models for Reference Point Calculation</u>

To consider these environmentally explicit models stock recruitment models in the context of reference points, it is necessary to summarize model parameters. For the Georges Bank stock, there was no demonstrated benefit of the environmentally-explicit model over the standard model, so reference points should be calculated from the standard model. For the Southern New England stock, an important issue in the standard stock recruitment model is the perceived need to bound the model parameters in both the prior stock assessment (NEFSC 2008) and in the current assessment. Specifically, the standard model estimates a high asymptotic recruitment (Table 7). Bounding asymptotic recruitment to the mean observed in a series of high recruitment years results in a very different model. At the mean environmental conditions, the unbounded environmentally-explicit model has a lower asymptotic recruitment (Table 7) and one benefit of this model is the lack of need for bounded parameters. For the Gulf of Maine stock, the standard model is almost identical to the environmentally-explicit model under mean conditions (Figure 8).

Another potential benefit for the environmentally explicit models is to forecast recruitment under different environmental conditions. Over the assessment record, there has been no change in winter air temperature (Figure 10). Further, the ability to forecast winter air temperatures in the 1-5 year range is limited at best. There is some skill in statistical seasonal forecasts with several months lead time (Cohen et al. 2010) and developing forecast skill on the decadal scale is a major topic of research in the climate modeling community (Smith et al. 2007, Keenlyside et al. 2008), but interannual forecasts with demonstrated skill are few. Thus, the environmental models developed here can be used with a mean environment to calculate reference points (Table 7 and 8). Additionally, scenarios could be evaluated calculating reference points under an assumption of warm winters and an assumption of cool winters to better inform management in the short-term.

Discussion

The results of the analyses support Manderson (2008) earlier finding. Recruitment in coastal stocks of winter flounder is related to temperature during the spawning season. Importantly, recruitment is also dependent on spawning stock biomass and the environmentally-explicit stock-recruitment models capture the combined effect of environment and stock size. The temperature effect is strongest in the Southern New England stock, where the species is at the southern extent of its range. The signal is less pronounced in the Gulf of Maine, but recruitment is still linked to winter temperatures. The effect of environment on recruitment of Georges Bank winter flounder is less clear. There is a lot of variability in the stock-recruitment relationship and none of this variability is explained with the environmental terms considered here. Whether other environmental factors play a role in Georges Bank winter flounder recruitment is an important question requiring future research.

The closer link to air temperatures for the Southern New England stock is explained by the argument that water temperatures in estuarine winter flounder spawning, larval, and juvenile habitats are more closely related to air temperature than to coastal water temperatures. Prior studies have found a close link between air temperature and estuarine water temperature (Hare and Able 2007). Future studies should explicitly treat the spatial dynamics of winter flounder in more detail (see Manderson 2008); such an approach could better examine the effect of environmental forcing on local populations.

One use of the environmentally-explicit models is to develop short-term and long-term forecasting models. Based on the above analyses, there is no trend in winter temperature over the past 30 years and thus short-term forecasts can be developed using the environmentally-explicit models assuming winter temperatures to be at their mean state. It may also be useful to develop short-term forecasts under warm temperatures and short temperatures to provide managers with a tangible understanding of the effect of temperature on the stocks. The environmentally-explicit models could also be used to develop longer-term forecasts following the approach of Hare et al. (2010). These forecasts would provide an assessment of the sustainability of the winter flounder fishery on the 30-100 time scale.

Table 1. Spawning stock biomass and recruitment pairs for the three stocks used in this study. Values are derived from the preferred model for all three stocks.

	GOM Stock		GB Stock		SNE Stock	
Year	SSB	R (lag -1)	SSB	R (lag -1)	SSB	R (lag -1)
1982	12,506	11,871	17,380	8,338	19,392	64,782
1983	8,609	9,055	16,473	17,881	20,108	43,197
1984	6,552	10,758	10,532	16,791	18,093	37,470
1985	4,747	9,182	6,256	21,914	15,948	43,484
1986	3,995	7,312	7,817	15,543	11,500	35,777
1987	3,717	6,885	8,082	26,317	9,087	34,914
1988	2,884	6,009	6,681	14,913	7,500	34,040
1989	2,521	5,967	5,299	9,881	6,205	20,447
1990	1,759	6,214	6,895	13,239	5,413	15,437
1991	1,490	7,263	6,791	6,424	5,479	17,117
1992	1,545	8,194	5,587	5,205	5,762	24,841
1993	1,487	8,007	4,843	7,314	4,977	18,385
1994	1,664	7,577	3,781	22,836	3,941	24,687
1995	1,797	8,735	3,424	16,323	3,990	20,118
1996	2,285	8,527	4,724	16,273	5,732	28,272
1997	3,030	8,100	6,901	18,754	6,481	22,122
1998	3,323	8,079	7,421	18,351	7,510	15,453
1999	3,648	5,864	9,761	14,432	7,753	12,809
2000	3,826	5,561	13,790	8,975	8,213	15,110
2001	4,040	6,196	10,722	7,279	8,941	7,454
2002	4,139	7,580	10,200	6,063	8,124	7,507
2003	4,198	10,686	9,490	5,520	6,045	15,790
2004	3,895	10,637	5,510	5,555	5,555	14,182
2005	4,338	10,007	5,305	10,493	4,911	8,259
2006	4,904	10,211	5,943	15,577	4,505	7,541
2007	5,623	8,928	6,229	18,849	5,194	13,494
2008	5,632	6,235	6,457	4,032	6,221	8,749
2009	5,817	4,673	7,917	22,530	5,850	8,711

Table 2. Environmental variables used in this study and their source.

Variable	Abbreviation		Stocks	Source
Southern New England Air Temperature	aSNE	three 2 monthly periods	SNE	http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html
Georges Bank Air Temperature	aGB	three 2 monthly periods	GB	http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html
Gulf of Maine Air Temperature	aGOM	three 2 monthly periods	GOM	http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html
Woods Hole Coastal Water Temperature	WH	three 2 monthly periods	GB, SNE	http://www.nefsc.noaa.gov/epd/ocean/MainPage/ioos.html
Boothbay Harbor Coastal Water Temperature	BH	three 2 monthly periods	GOM	http://www.nefsc.noaa.gov/epd/ocean/MainPage/ioos.html
Atlantic Multidecadal Oscillation	AMO	0 year lag	GB, GOM, SNE	http://www.cdc.noaa.gov/Correlation/amon.us.long.data
North Atlantic Oscillation (DJFM)	NAO	0, 1, and 2 year lags	GB, GOM, SNE	http://www.cgd.ucar.edu/cas/jhurrell/Data/naodjfmindex.asc
Gulf Stream Index – Joyce and Zhang (2010)	GS-J	0 year lag	GB, GOM, SNE	Terry Joyce (pers. comm.)
Gulf Stream Index – Taylor and Stephens (1998)	GS-PLY	0 year lag	GB, GOM, SNE	http://www.pml-gulfstream.org.uk/Web2009.pdf

Table 3. List of standard and environmentally-explicit stock recruitment models used in the study. Formulation follows Levi et al. (2003).

Model Name	Model Formulation	Model
Beverton-Holt	$R = S/(b + aS)$	Standard / No Environment
Beverton-Holt	$R = Se^{cE}/(b + aS)$	Environmental Model 1 Controlling Effects (alters the rate of change of numbers of young fish in time)
Beverton Holt	$R = S/(b + ae^{cE}S)$	Environmental Model 2 Limiting Effects (alters the carrying capacity of the habitat for recruits)
Beverton Holt	$R = S/(be^{cE} + aS)$	Environmental Model 3 Masking Effects (determines the metabolic work needed for the maintenance of the individual.)

Table 4. Correlation matrix for the 21 environmental variables considered in this study. Significance denoted by color: p<0.05 yellow; p<0.01 orange; p<0.001 red.

Environmental Variables	GS-J-0	GS-PML-0	AMO-0	NAO-0	NAO-1	NAO-2	WH-JF	WH-MA	WH-MJ	BH-JF	BH-MA	BH-MJ	aSNE-JF	aSNE-MA	aSNE-MJ	aGB-JF	aGB-MA	aGB-MJ	aGOM-JF	aGOM-MA	aGOM-MJ
GS-J-0	1.00	0.54	-0.07	-0.02	0.33	0.46	0.20	0.21	0.15	0.32	0.26	0.19	0.19	0.05	0.02	0.38	0.29	0.20	0.12	-0.14	0.11
GS-PML-0	0.54	1.00	-0.23	0.31	0.40	0.53	0.22	0.24	0.28	0.32	0.05	0.06	0.19	0.10	0.09	0.35	0.21	0.33	0.15	-0.09	0.13
AMO-0	-0.07	-0.23	1.00	-0.22	-0.29	-0.49	0.25	-0.01	-0.34	0.27	0.47	0.69	0.26	0.17	0.12	0.13	-0.20	-0.40	0.24	-0.05	0.19
NAO-0	-0.02	0.31	-0.22	1.00	0.14	-0.09	0.26	0.25	0.24	-0.13	-0.42	-0.27	0.18	0.07	0.02	0.17	0.17	0.22	0.10	0.09	0.12
NAO-1	0.33	0.40	-0.29	0.14	1.00	0.17	-0.14	-0.06	0.28	-0.09	-0.20	-0.02	0.04	-0.07	0.12	0.10	0.19	0.32	-0.01	0.02	0.12
NAO-2	0.46	0.53	-0.49	-0.09	0.17	1.00	0.07	0.10	0.06	0.30	0.10	-0.21	-0.02	0.02	-0.08	0.07	0.08	0.08	-0.08	-0.14	-0.19
WH-JF	0.20	0.22	0.25	0.26	-0.14	0.07	1.00	0.63	0.28	0.54	0.33	0.20	0.81	0.36	0.26	0.74	0.16	0.10	0.73	0.21	0.28
WH-MA	0.21	0.24	-0.01	0.25	-0.06	0.10	0.63	1.00	0.47	0.17	0.24	-0.07	0.65	0.73	0.34	0.68	0.60	0.34	0.67	0.63	0.23
WH-MJ	0.15	0.28	-0.34	0.24	0.28	0.06	0.28	0.47	1.00	-0.06	-0.29	-0.11	0.26	0.14	0.71	0.25	0.33	0.67	0.27	0.29	0.62
BH-JF	0.32	0.32	0.27	-0.13	-0.09	0.30	0.54	0.17	-0.06	1.00	0.72	0.50	0.50	0.05	0.04	0.47	-0.12	-0.10	0.42	-0.15	0.10
BH-MA	0.26	0.05	0.47	-0.42	-0.20	0.10	0.33	0.24	-0.29	0.72	1.00	0.70	0.41	0.36	0.00	0.42	0.08	-0.30	0.38	0.11	-0.07
BH-MJ	0.19	0.06	0.69	-0.27	-0.02	-0.21	0.20	-0.07	-0.11	0.50	0.70	1.00	0.22	0.08	0.23	0.22	-0.10	-0.18	0.21	-0.12	0.24
aSNE-JF	0.19	0.19	0.26	0.18	0.04	-0.02	0.81	0.65	0.26	0.50	0.41	0.22	1.00	0.39	0.13	0.87	0.13	0.09	0.93	0.25	0.22
aSNE-MA	0.05	0.10	0.17	0.07	-0.07	0.02	0.36	0.73	0.14	0.05	0.36	0.08	0.39	1.00	0.29	0.39	0.59	0.13	0.39	0.77	-0.01
aSNE-MJ	0.02	0.09	0.12	0.02	0.12	-0.08	0.26	0.34	0.71	0.04	0.00	0.23	0.13	0.29	1.00	0.16	0.38	0.37	0.16	0.38	0.67
aGB-JF	0.38	0.35	0.13	0.17	0.10	0.07	0.74	0.68	0.25	0.47	0.42	0.22	0.87	0.39	0.16	1.00	0.38	0.24	0.91	0.27	0.24
aGB-MA	0.29	0.21	-0.20	0.17	0.19	0.08	0.16	0.60	0.33	-0.12	0.08	-0.10	0.13	0.59	0.38	0.38	1.00	0.51	0.12	0.74	0.15
aGB-MJ	0.20	0.33	-0.40	0.22	0.32	0.08	0.10	0.34	0.67	-0.10	-0.30	-0.18	0.09	0.13	0.37	0.24	0.51	1.00	0.11	0.35	0.63
aGOM-JF	0.12	0.15	0.24	0.10	-0.01	-0.08	0.73	0.67	0.27	0.42	0.38	0.21	0.93	0.39	0.16	0.91	0.12	0.11	1.00	0.25	0.24
aGOM-MA	-0.14	-0.09	-0.05	0.09	0.02	-0.14	0.21	0.63	0.29	-0.15	0.11	-0.12	0.25	0.77	0.38	0.27	0.74	0.35	0.25	1.00	0.11
aGOM-MJ	0.11	0.13	0.19	0.12	0.12	-0.19	0.28	0.23	0.62	0.10	-0.07	0.24	0.22	-0.01	0.67	0.24	0.15	0.63	0.24	0.11	1.00

Table 5. Akaike Information Criteria statistics for the top ten ranked models for each stock.

Stock	Model Rank	Model	Variable	AICc	delta	weight	cumulative weight
Southern New England	1	BH env M2	aSNE-JF	505.12	0.00	0.214	0.214
	2	BH env M2	GS-J-0	505.62	0.50	0.166	0.380
	3	BH env M1	aSNE-JF	505.79	0.66	0.153	0.533
	4	BH env M3	aSNE-JF	506.15	1.03	0.128	0.661
	5	BH env M2	AMO-0	507.47	2.35	0.066	0.727
	6	BH env M3	AMO-0	508.00	2.88	0.051	0.778
	7	BH env M1	AMO-0	508.05	2.93	0.049	0.827
	8	BH env M1	GS-J-0	509.17	4.05	0.028	0.855
	9	BH env M3	GS-J-0	509.21	4.09	0.028	0.883
	10	BH env M1	WH-JF	509.47	4.35	0.024	0.907
Georges Bank	1	BH std M	none	496.04	0.00	0.082	0.082
	2	BH env M3	aGB-JF	496.76	0.72	0.057	0.139
	3	BH env M1	aGB-MJ	496.95	0.91	0.052	0.191
	4	BH env M2	aGB-MJ	496.96	0.92	0.052	0.243
	5	BH env M3	GS-PML-0	497.29	1.25	0.044	0.287
	6	BH env M2	GS-J-0	497.55	1.51	0.039	0.326
	7	BH env M1	GS-J-0	497.56	1.51	0.039	0.365
	8	BH env M2	WH-MJ	498.04	2.00	0.030	0.395
	9	BH env M1	WH-MJ	498.06	2.02	0.030	0.425
	10	BH env M2	NAO-0	498.15	2.11	0.029	0.454
Gulf of Maine	1	BH env M2	aGOM-JF	423.39	0.00	0.108	0.108
	2	BH env M1	aGOM-JF	423.50	0.10	0.103	0.211
	3	BH env M2	aGOM-MJ	424.72	1.33	0.056	0.267
	4	BH env M2	BH-JF	424.83	1.44	0.053	0.320
	5	BH env M1	aGOM-MJ	424.84	1.45	0.052	0.372
	6	BH env M1	BH-JF	424.86	1.47	0.052	0.424
	7	BH std M	none	424.97	1.58	0.049	0.473
	8	BH env M2	aGOM-MA	425.04	1.64	0.048	0.521
	9	BH env M1	aGOM-MA	425.13	1.74	0.045	0.566
	10	BH env M3	BH-JF	425.63	2.24	0.035	0.601

Table 6. Model weights, explained variance and evidence ratios for best environmentally-explicit models compared to best standard model.

Stock	Model	Variable	W	r^2	Evidence Ratio
Southern New England	BH env M2	aSNE-JF	0.214	0.74	105.8
	BH std M	None	0.002	0.60	
Georges Bank	BH env M3	aGB-JF	0.057	0.07	0.7
	BH std M	None	0.082	0.00	
Gulf of Maine	BH env M2	aGOM-JF	0.108	0.21	2.2
	BH std M	None	0.003	0.07	

Table 7. Results of Beverton-Holt stock recruitment model fits for the Southern New England stock. Model parameters are provided following Table 2 and asymptotic recruitment is calculated as $\frac{1}{a}$. The lognormal deviate ($\frac{\sum(\ln(R)-\ln(\hat{R}))^2}{n-1}$), mean environmental term, and standard deviation of the environmental term for the environmentally-explicit model are also provided.

	No prior – standard model	No prior – environmental model aSNE-JF	Prior a=50,409,200 standard model	Prior a=50,409,200 environmental model
b	0.3482	0.2777	0.1879	0.2842
a	2.4433e-6	2.2278e-5	1.9836e-5	1.9840e-5
c	NA	0.6203	NA	0.6129
ae^{cT}	NA	8.2171e-6	NA	7.4048e-6
Asym Rec	409,280,000	121,700,000	50,414,000	135,050,000
lognormal deviate	0.2464	0.1963		
$\bar{E}$		-1.6079		
σ_E		1.6654		

Table 8. Results of Beverton-Holt stock recruitment model fits for the Gulf of Maine stock. Model parameters are provided following Table 2 and asymptotic recruitment is calculated as $\frac{1}{a}$. The lognormal deviate ($\frac{\sum(\ln(R)-\ln(\hat{R}))^2}{n-1}$), mean environmental term, and standard deviation of the environmental term are also provided.

	No prior – standard model	No prior – environmental model
b	0.0509	0.0533
a	1.0893e-4	1.5225e-4
c	Na	0.0599
ae^{cT}	Na	1.0857e-4
Asym Rec	9,179,800	9,211,000
lognormal deviate	0.0540	0.0487
$\bar{E}$		-5.6454
σ_E		1.6562

Figure 1. Map showing locations of temperature data used in this study. Air temperatures were derived from the NCEP Reanalysis. Grid denoted as thin gray lines and grid points used in air temperature calculations marked by circles (red – Southern New England, green – Georges Bank, blue – Gulf of Maine, cyan – regional). Coastal water temperatures were obtained for Woods Hole, Massachusetts (WH - red triangle) and Boothbay Harbor, Maine (BH - blue triangle). Data sources are provided in Table 2.

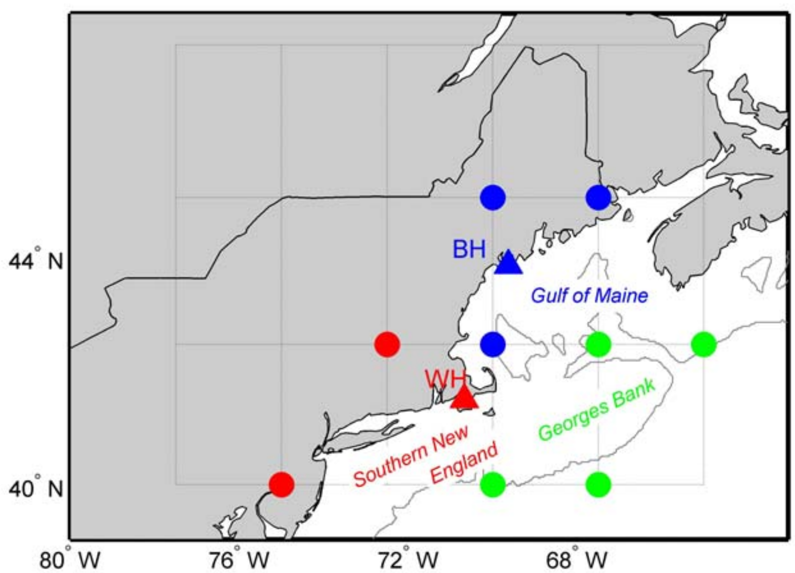


Figure 2. Representative time series for environmental variables considered here. Abbreviations for the variable names are provided in Table 2. Air and water temperatures are presented relative to their mean value. The large-scale environmental variables are presented as anomalies.

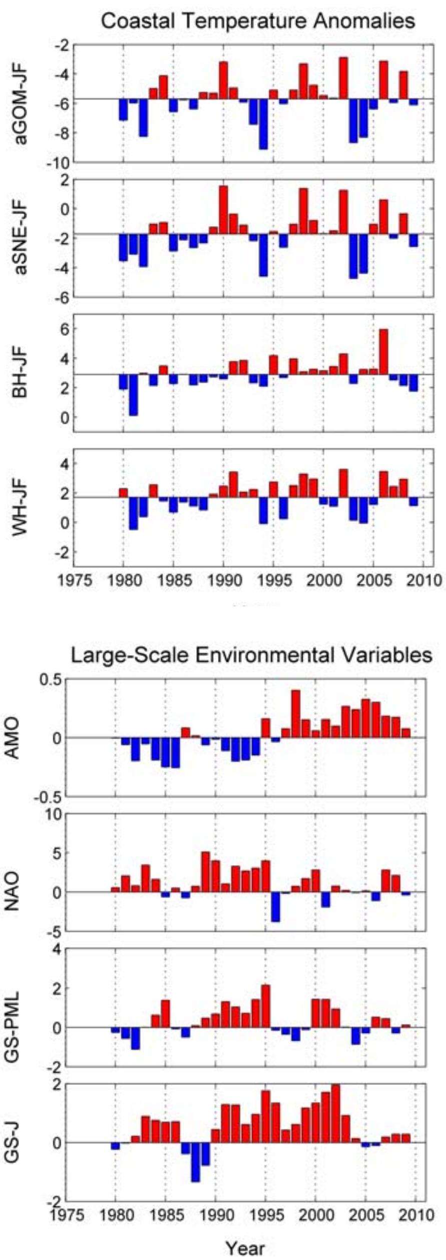


Figure 3. Comparison of stock-recruitment data and Beverton-Holt models for the three stocks of winter flounder.

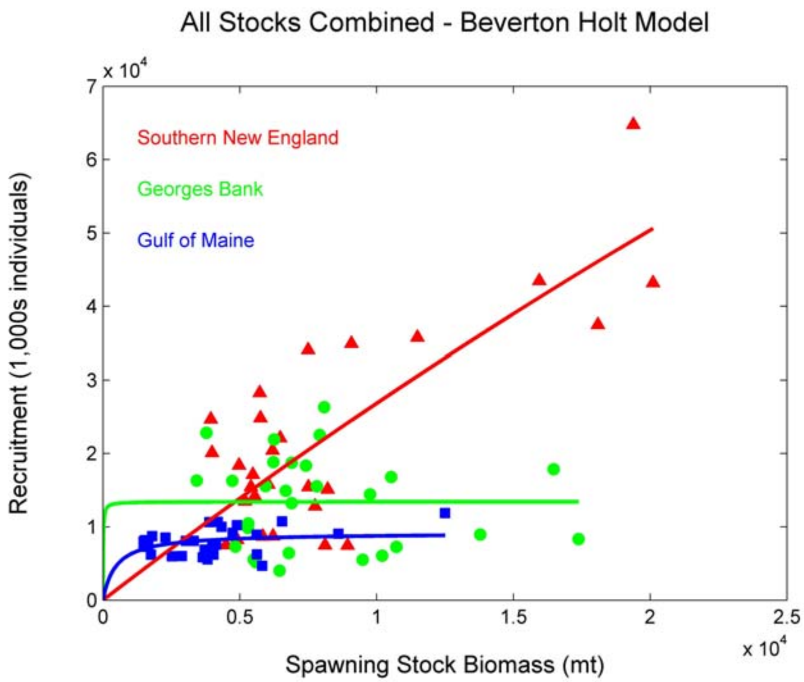


Figure 4. Comparison of the residuals of the stock-recruitment relationships for the three winter flounder stocks based on the standard Beverton-Holt model.

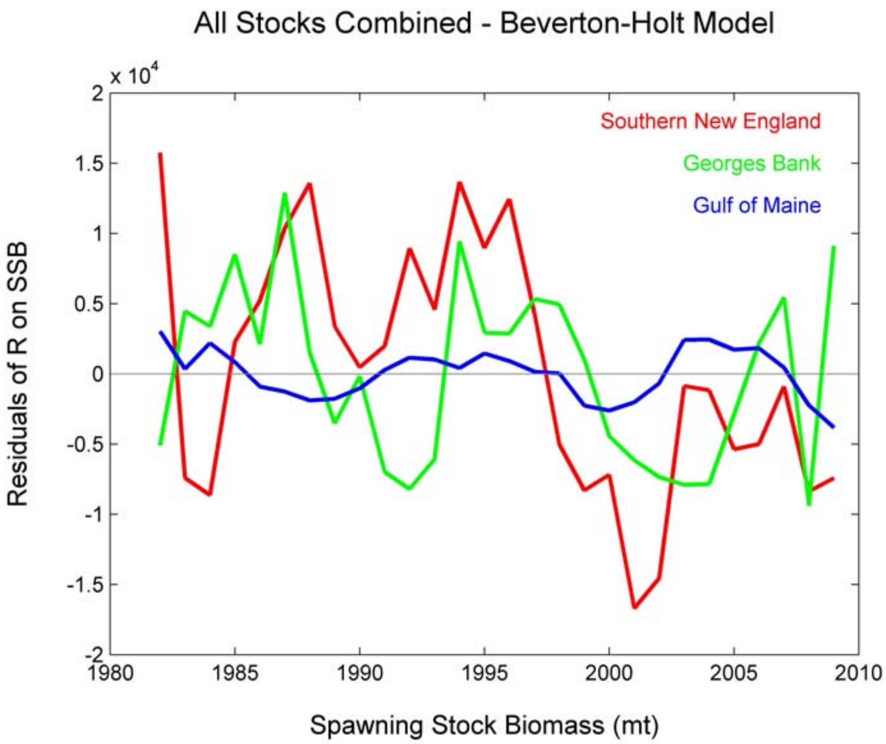


Figure 5. Serial correlation of the residuals of the stock recruitment relationship making the three pairwise comparisons: SNE vs. GB, SNE vs. GOM, and GB vs. GOM. Window for serial correlations set at 10 years.

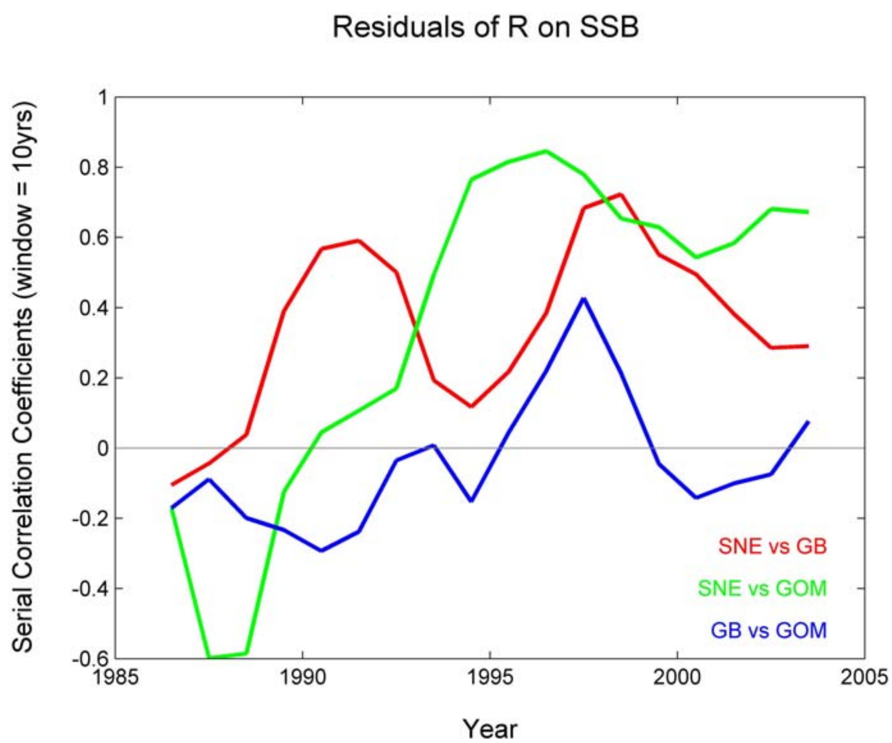


Figure 6. Environmentally-explicit stock recruitment relationships for the Southern New England stock of winter flounder. The best overall environmental model is shown as is the standard model (gray). Symbols are color coded to the value of the environmental variable and model predictions for mean environment and ± 1 standard deviation of the environmental variable are shown. The specific model and environmental variable are noted in the upper left hand corner (see Table 1 and 2 for abbreviations).

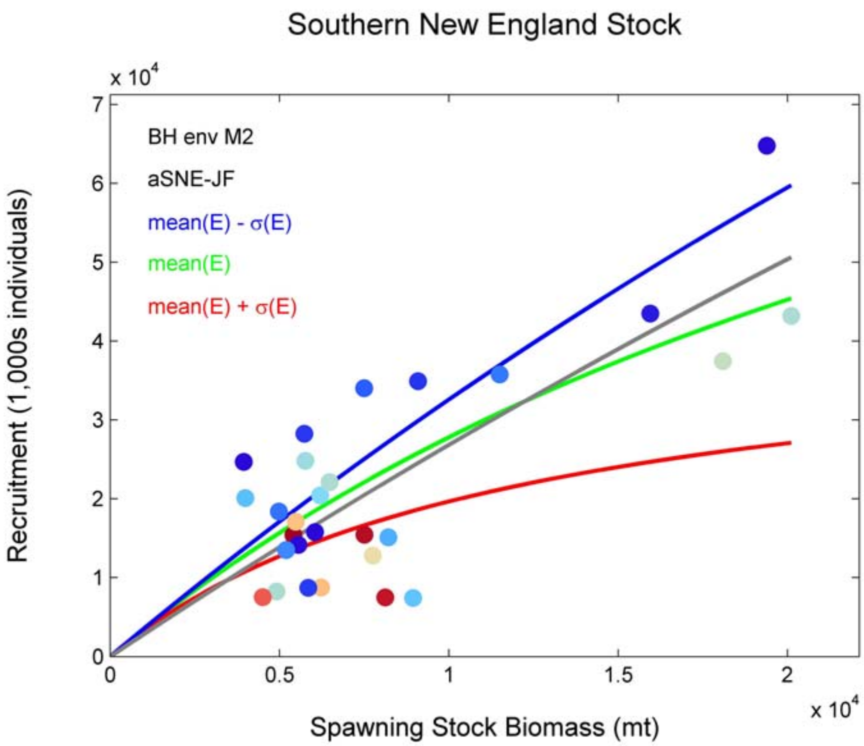


Figure 7. Environmentally-explicit stock recruitment relationships for the Georges Bank stock of winter flounder. The best overall environmental model is shown as is the standard model (gray). Symbols are color coded to the value of the environmental variable and model predictions for mean environment and ± 1 standard deviation of the environmental variable are shown. The specific model and environmental variable are noted in the upper left hand corner (see Table 1 and 2 for abbreviations).

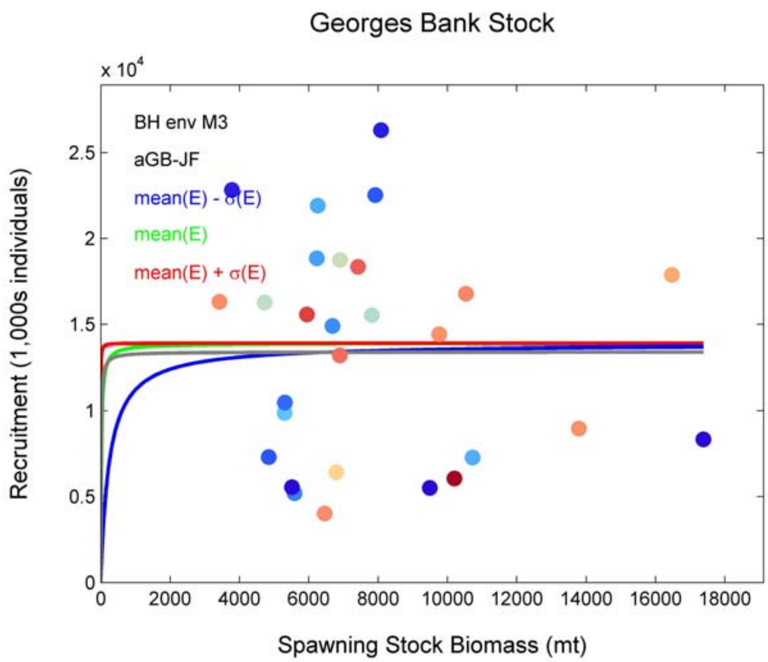


Figure 8. Environmentally-explicit stock recruitment relationships for the Gulf of Maine stock of winter flounder. The best overall environmental model is shown as is the standard model (gray). Symbols are color coded to the value of the environmental variable and model predictions for mean environment and ± 1 standard deviation of the environmental variable are shown. The specific model and environmental variable are noted in the upper left hand corner (see Table 1 and 2 for abbreviations).

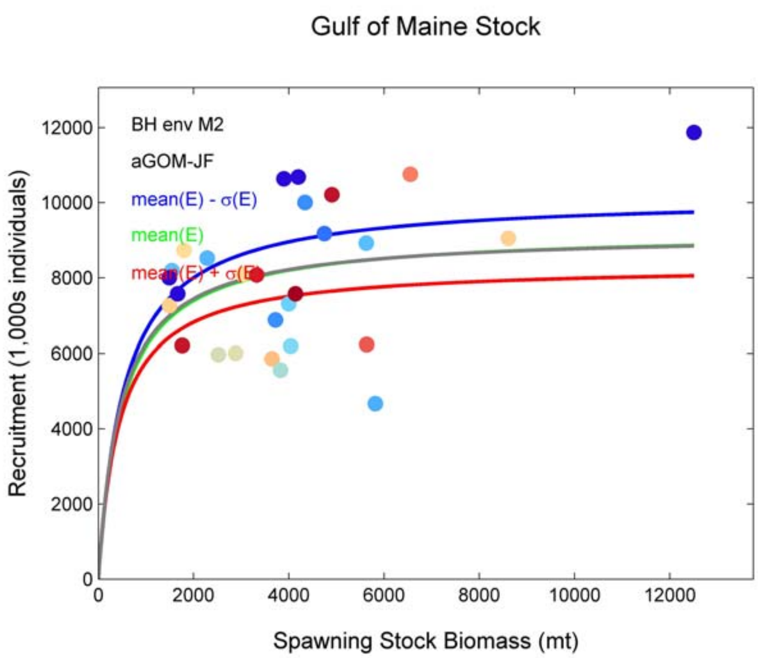
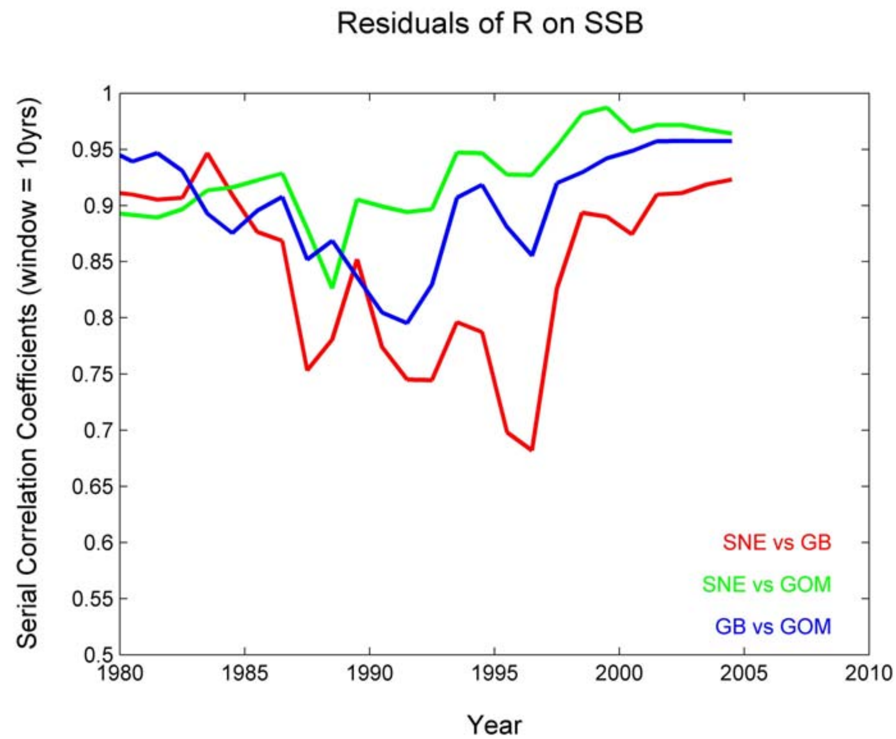


Figure 9. Serial correlation of winter air temperatures across the region making the three pairwise comparisons: SNE vs. GB, SNE vs. GOM, and GB vs. GOM.



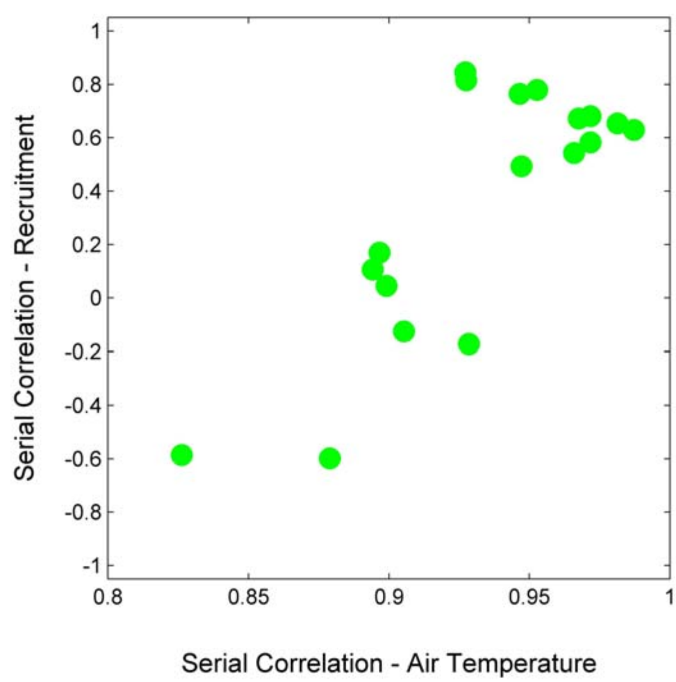
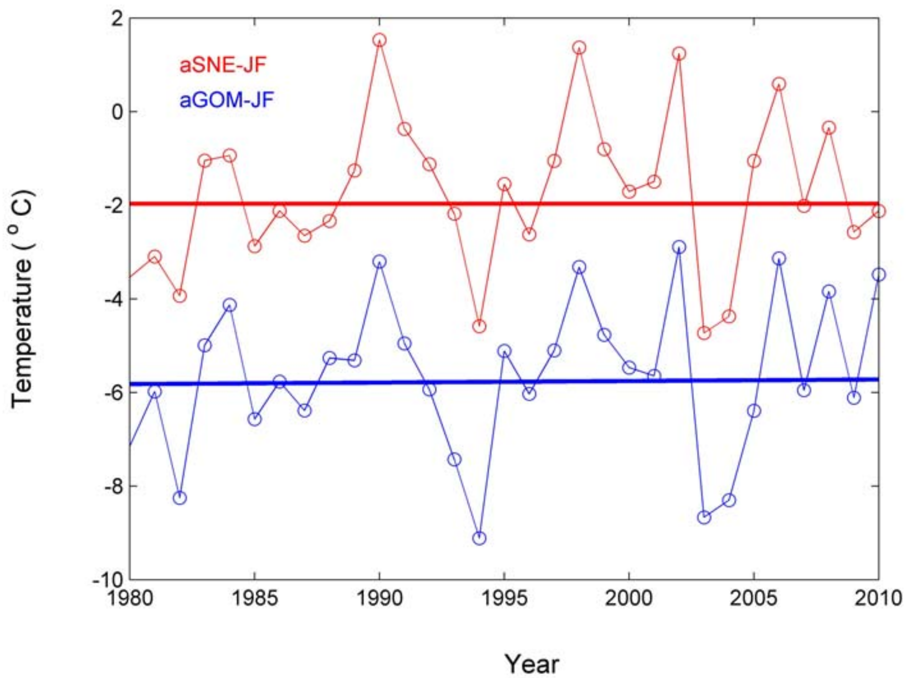


Figure 10. Time series of winter air temperature over Southern New England and the Gulf of Maine for the period of the assessment. The lines represent the linear regression; the slopes of both were not significantly different than zero.



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SDWG Background WP#14
May 2011
TOR4-Uncertainty Landings

A Working Paper in support of SARC 52 Winter Flounder TOR 4 "Perform a sensitivity analysis which examines the impact of allocation of catch to stock areas on model performance (in TOR 5)."

Measures of Uncertainty in the Trip-based Allocated Landings

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April 2011

This information is distributed solely for the purpose of pre-dissemination peer review. It has not been formally disseminated by NOAA. It does not represent any final agency determination or policy.

Brief Summary

- Prior to 1994, Dealer landings had area fished determined by the port agent based on interviews conducted with the vessel captains; not all trips were interviewed. For non-interviewed trips, port agent would use knowledge gained through prior interviews of the vessel and the fleet to assign statistical area
- Dealer allocated landings (1994 onward) have area fished determined by a multi-tier trip-based allocation method (Wigley et al 2008) that utilizes Vessel Trip Report data
- For allocated landings, a meta data element (Alevel) indicate whether a trip matched at one of the four tiers, Alevel A (direct 1:1 trip match between Dealer and VTR data), Alevel B (vessel match between Dealer and VTR data); Alevel C (fleet match between Dealer and VTR data) or Alevel D (broad fleet match between Dealer and VTR data)
- Alevel A is equivalent to a port agent's interview prior to 1994 (intv = 1)
- Trips that matched at Alevel B, C or D have an area assigned on a probabilistic basis using VTR data.
- The probability associated with each trip can be used to approximate the uncertainty associated with landings at Alevel = B, C or D.
- Calculated the variance and coefficient of variation of an allocated trip (and associated landings) using the multinomial distribution:

  Eq. 1 $V(T) = pq = p * (1-p)$

  Eq. 2 $CV(T) = \mathrm{sqrt}(pq)$

  Eq. 3 $CV(L) \sim CV(T)$

  Eq. 4 $V(L) = (CV(T) * L)^2$

  Eq 5. $Var\_mt = prob *(1-prob) * mt^2$

  Where p is the probability (*prob*) of the trip (stored in the Dealer AA data)
  T is the given allocated trip at Alevel =B, C, or D
  L are the landings associated with an allocated trip at Alevel = B, C or D.

- Winter flounder stock landings are summarized by Alevel and year (Figures 1 – 3)
  - High percentage of winter flounder stock landings match at Alevel = A
  - generally ranges between 60% and 68%
  - Level A percentages are greater than interview percentages for SNE and GOM winter flounder stocks
- Winter flounder stock landings and 95% confidence intervals are summarized by year (Table 1).
  - No measure of uncertainty for landings prior to 1994

- Explore the magnitude of under-reporting of statistical areas on Vessel Trip Reports (VTR) using three years of matched trips from Northeast Fisheries Observer Program (OB) and VTR data for 2007, 2008 and 2009. OB and VTR trips were matched using the M Palmer's mid-point match method (Palmer and Wigley 2007). A "diagnostic ratio" (observed kept weight of all species divided by the VTR kept weight of all species) was used to create a subset of matched trips and applied to Dealer trips with Alevel = A. Percentage of trips under-reporting statistical areas in the subset of trips ranged between 7% and 13% (Table 2).
    - Further exploration of the 'matched set' is needed
    - Utilizing data leveraging between VMS and VTR is the best way to improve VTR reporting compliance

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Table 1. Winter flounder stock landings (mt) with 95% confidence intervals, and percentage of uncertain landings associated with the trip-bases allocation (Alevel = B, C, & D).

Year	GOM	95 CI	%	GB	95 CI	%	SNE	95 CI	%	Area 000	UNID stock	
1982	2798.7			2958.6			8420.1				0.2	
1983	2099.1			3893.8			7963.7					
1984	1706.0			3926.6			7635.2					
1985	1583.4			2151.0			6005.4				23.2	Grand Banks
1986	1216.0			1761.3			4639.4				7.1	Grand Banks
1987	1159.9			2636.6			4482.7					
1988	1250.6			2803.9			3932.1				0.0	
1989	1252.9			1880.1			3846.9					
1990	1117.0			1898.0			3963.5					
1991	1008.3			1814.3			4782.8					
1992	824.6			1821.5			3815.5					
1993	611.5			1659.6			3010.4				2.3	
1994	528.5	4.6	0.9%	929.1	16.3	1.8%	2113.7	18.3	0.9%	30.5	1.2	stat area 460s
1995	699.9	11.3	1.6%	728.3	16.0	2.2%	2582.9	18.1	0.7%	18.1		
1996	602.2	11.5	1.9%	1366.3	24.0	1.8%	2767.7	29.3	1.1%	23.9		
1997	566.3	16.4	2.9%	1219.0	24.4	2.0%	3515.5	47.8	1.4%	42.6		
1998	640.7	7.8	1.2%	1308.0	32.1	2.5%	3134.8	42.1	1.3%	5.4		
1999	348.5	4.7	1.3%	937.5	21.5	2.3%	3342.8	32.5	1.0%	8.3	0.1	
2000	533.1	5.6	1.0%	1603.1	31.0	1.9%	3692.8	28.1	0.8%	13.7		
2001	691.0	11.3	1.6%	1667.4	32.6	2.0%	4509.0	32.4	0.7%	63.0		
2002	658.2	14.3	2.2%	2079.7	34.0	1.6%	3033.2	33.2	1.1%	106.4		
2003	716.0	4.9	0.7%	2828.2	38.9	1.4%	2301.8	25.8	1.1%	46.0		
2004	573.0	6.2	1.1%	2647.2	39.8	1.5%	1593.3	39.0	2.4%	106.0		
2005	282.5	4.4	1.5%	1882.0	24.0	1.3%	1168.0	26.8	2.3%	334.5		
2006	180.7	2.4	1.3%	814.1	13.0	1.6%	1632.0	14.5	0.9%	119.4		
2007	209.8	1.8	0.9%	785.9	15.0	1.9%	1525.5	17.4	1.1%	155.1		
2008	242.4	2.9	1.2%	944.5	14.7	1.6%	1043.0	12.9	1.2%	117.2		
2009	261.3	1.7	0.7%	1656.4	30.8	1.9%	242.1	10.9	4.5%	52.6	2.2	stat area 468
2010	129.4	1.6	1.3%	1249.6	32.4	2.6%	157.8	13.9	8.8%	28.5		
avearge			1.4%			1.9%			1.8%			

Table 2. Number and percentage of matched trips for 2007, 2008 and 2009 for trips where the count of observed statistical areas equaled the count of statistical areas reported in the VTR (SA Count Equal) and where the counts of statistical areas were not equal (SA Count Not Equal), for single and multiple statistical areas reported on the observed trip. (SA = statistical area; Multi = multiple).

	2007		2008		2009	
Stat Area Level	**Trips**	**%**	**Trips**	**%**	**Trips**	**%**
Matched Trips Alevel = A	929		874		1062	
SA Count Equal, Single SA	670	72.1%	587	67.2%	755	71.1%
SA Count Equal, Multi SA	28	3.0%	35	4.0%	28	2.6%
SA Count Not Equal, Multi SA	**231**	**24.9%**	**252**	**28.8%**	**279**	**26.3%**
Matched Trips Alevel = A and landed Winter Flounder	305		340		327	
SA Count Equal, Single SA	208	68.2%	230	67.6%	243	74.3%
SA Count Equal, Multi SA	13	4.3%	7	2.1%	12	3.7%
SA Count Not Equal, Multi SA	**84**	**27.5%**	**103**	**30.3%**	**72**	**22.0%**
Stock Level						
Multi SA	97	31.8%	110	32.4%	84	25.7%
Stock Count Equal	66	21.6%	66	19.4%	62	19.0%
Stock Count Not Equal	**31**	**10.2%**	**44**	**12.9%**	**22**	**6.7%**

Figure 1. Percentage of Gulf of Maine winter flounder landings, by Alevel and year.

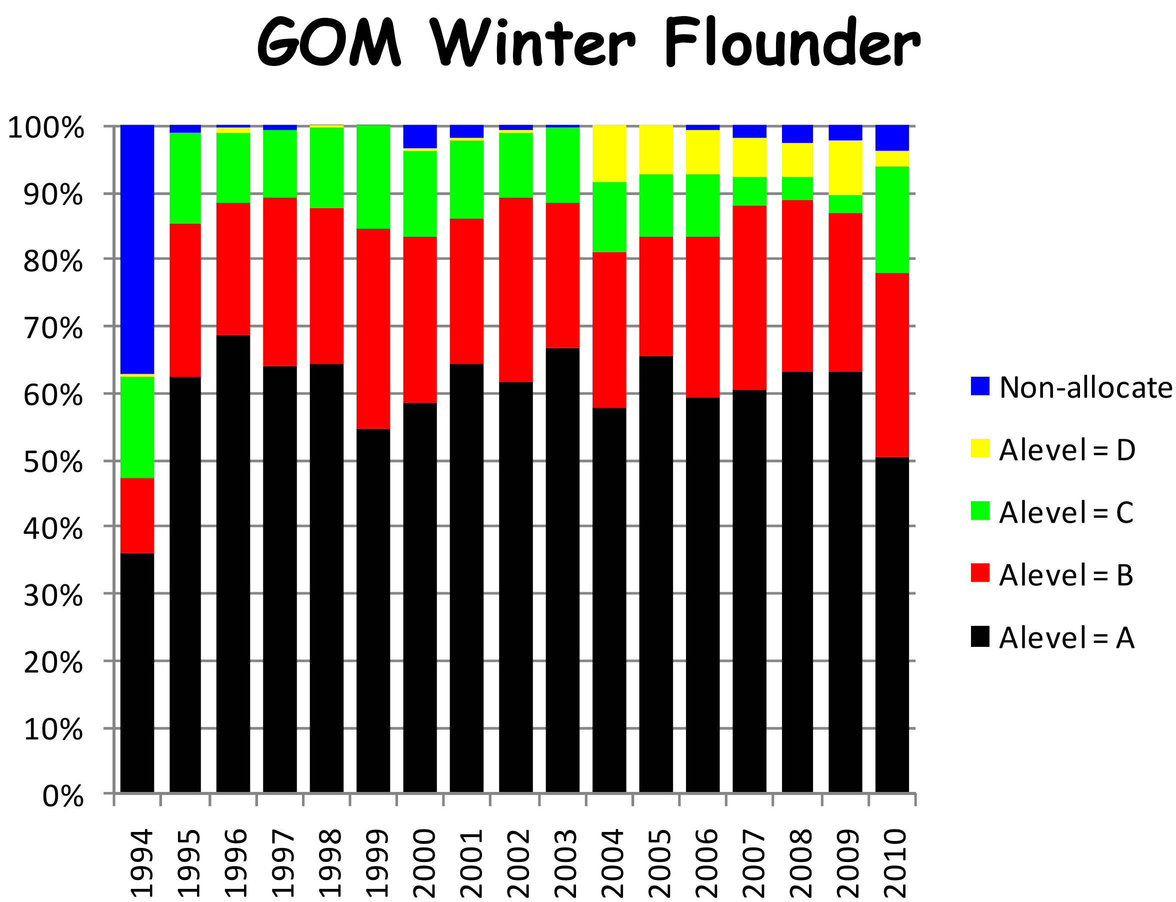


Figure 2. Percentage of Georges Bank winter flounder landings, by Alevel and year.

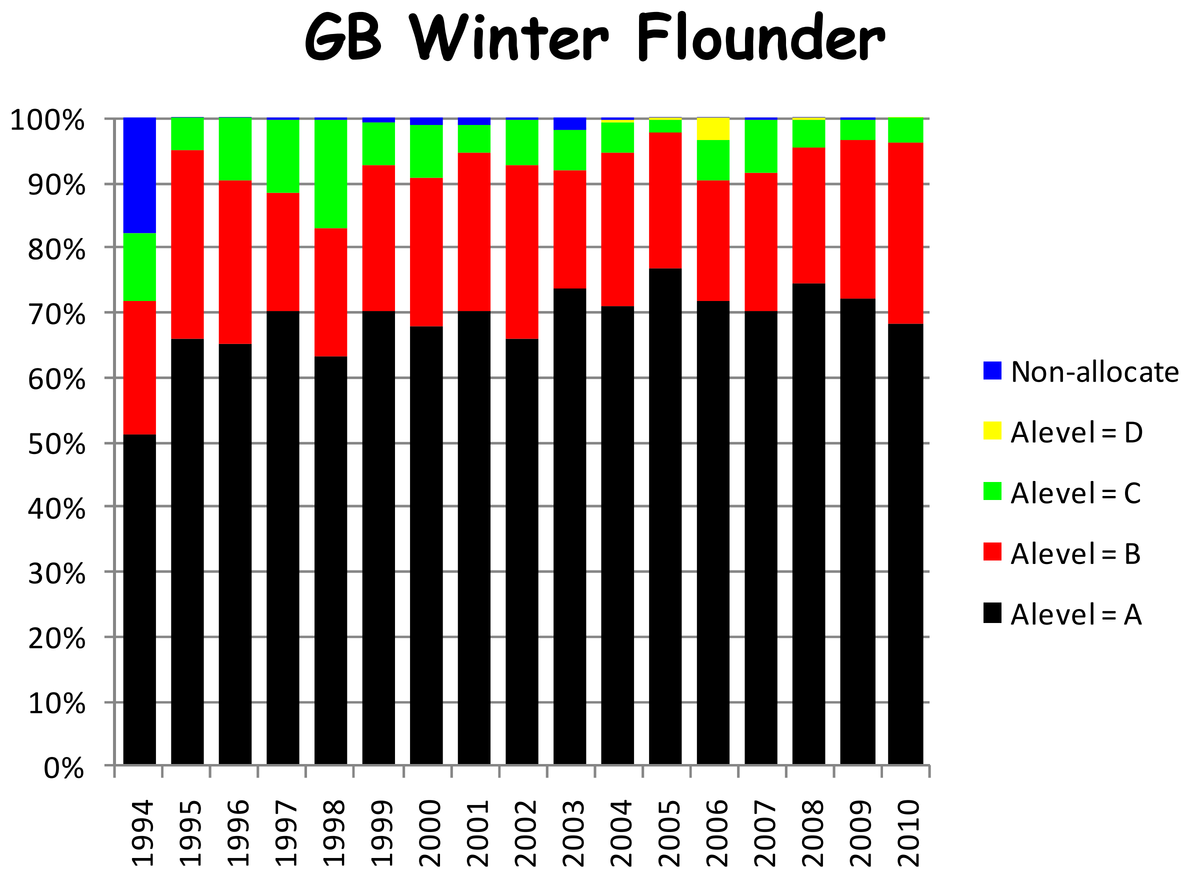


Figure 3. Percentage of Georges Bank winter flounder landings, by Alevel and year.

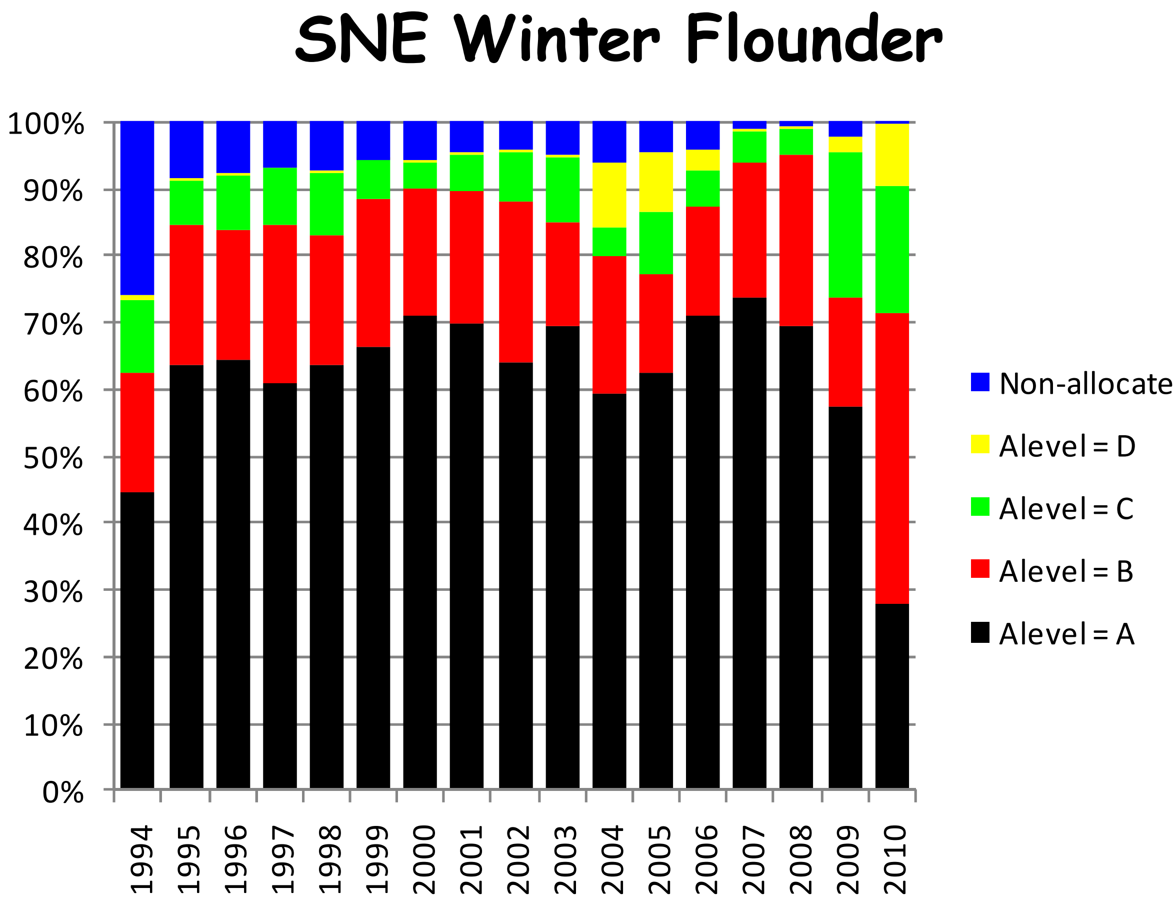


Figure 4. Winter flounder stock landings (mt) with 95% confidence intervals associated with the trip-bases allocation (Alevel = B, C, & D).

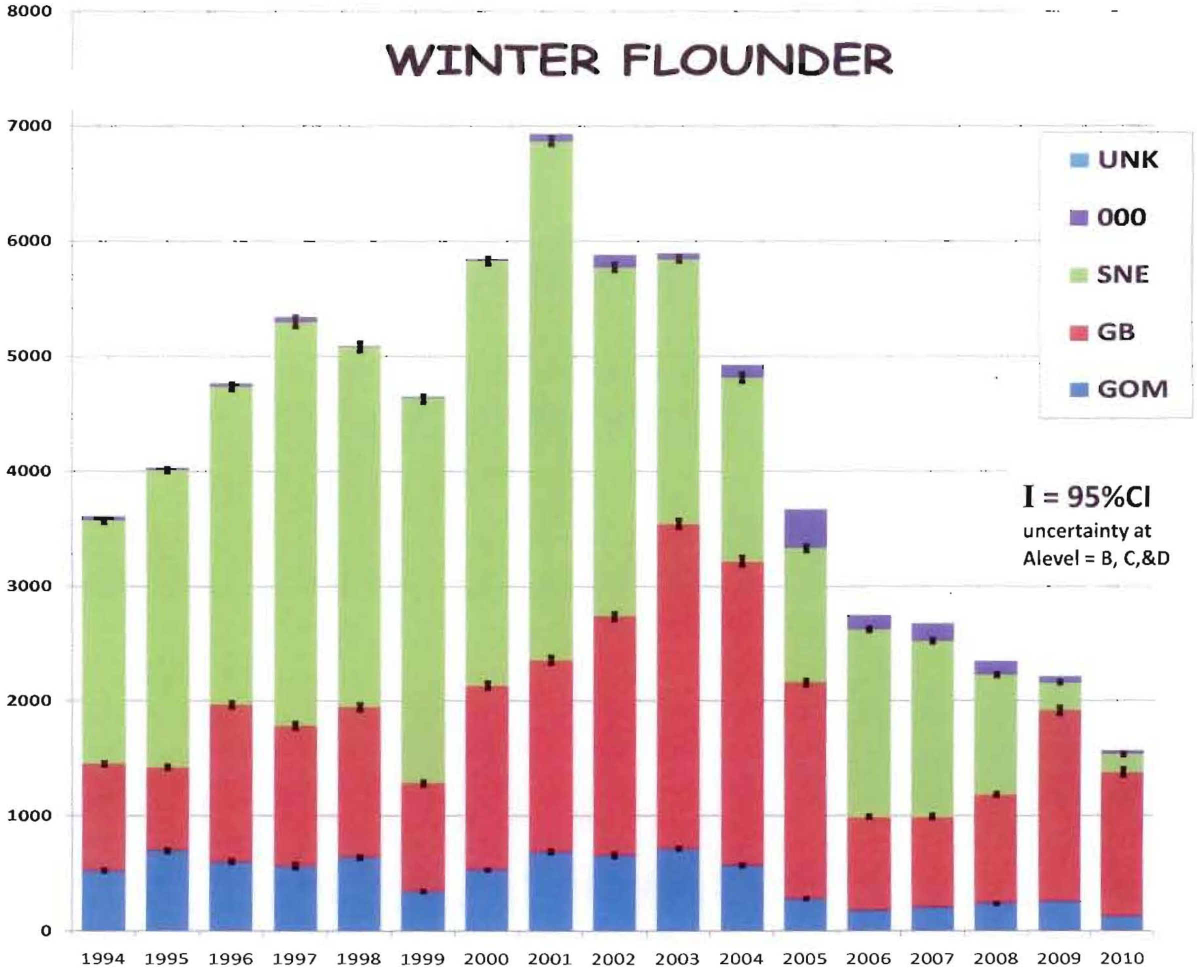
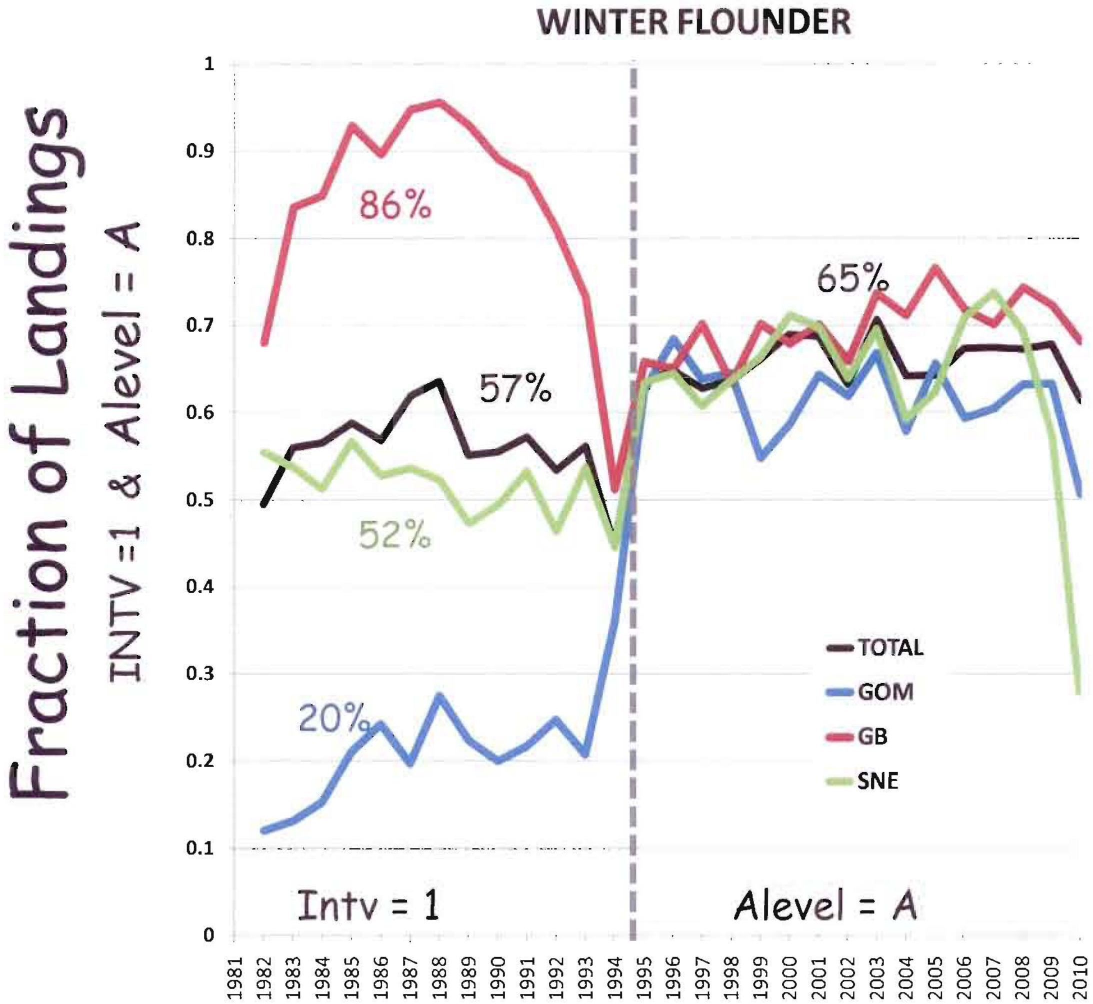


Figure 5. Fraction of winter flounder stock landings associated with Alevel = A of the trip-based allocation (1994 onward) and port agents' interviews (intv = 1; prior to 1993). Time series average percentage of stock landings are given.



SARC 52 Southern Demersal Working Group (SDWG)
Working Paper: Re-analysis of Howe and Coates (1975)
April 29 2011
Anthony Wood
**************DRAFT: DO NOT DISTRIBUTE OR CITE**************

Winter flounder natural mortality derived from data in Howe and Coates (1975) using instantaneous rates tagging models.

Introduction

Tag based estimates of natural mortality for winter flounder (*Pseudopleuronectes americanus*) off New England are limited to a few studies carried out decades ago (Dickie and McCraken 1955, Poole 1966, Howe and Coates 1975). These studies implemented ratio based formulas of tag releases and recoveries to estimate natural mortality without modeling. The methodology and model development of tag-recovery analysis has advanced since these early studies were conducted (Brownie et al. 1985, Lebrenton et al. 1992, Hoenig et al. 1998). The purpose of this analysis was to apply a more advanced tagging model to data from Howe and Coates (1975) to estimate natural mortality. The tagging model fit to the data was the instantaneous rates formulation of Brownie et al. (1985) recovery model s (Hoenig et al. 1998).

Methods

A subset of tag-recovery data from Howe and Coates (1975) detailing 5 release cohorts (Table 1) were analyzed with 4 different parameterizations of the Hoenig et al. (1998) instantaneous rates tagging model. All models assumed a constant natural mortality across time and cohorts as well as constant fishing mortality throughout each year. It was also assumed that tags were not lost or missed, and that tagging did not influence survival, recovery rate, or mixture within the overall population.

Brownie et al. (1985) models use survival (*S*) and recovery rate (*f*) parameters to model tag returns. The instantaneous rates tagging model specifies the survival (*S*) and recovery rate (*f*) parameters in terms of fishing (*F*) and natural (*M*) mortality (Hoenig et al. 1998). Survival becomes:

$$S = e^{-(F+M)}$$

And recovery rate is:

$$f = \lambda \phi u$$

Where λ is the reporting rate (assumed 1.0 for all models) and ϕ is tag loss (assumed no tag loss in all models). Exploitation rate (*u*) is also specified in terms of *F* and *M*:

$$u = \frac{F}{F+M}\left(1 - e^{-(F+M)}\right)$$

Matrices of expected values for each model structure were developed (Table 2). Recoveries were modeled as multinomial random variables and parameters were estimated via maximum likelihood estimation. Akaike's information criterion (AIC) was used to rank and select the model with the best fit:

$$\text{AIC} = -2\ln(L) + 2K$$

Where *L* is the model likelihood and K is the number of parameters.

An over-dispersion estimate was derived for the general model (year and cohort parameterization) by dividing the model deviance by the degrees of freedom. To account for over-dispersion ($\hat{c}$) and for differences in effective sample size (*N*), a quasi likelihood adjusted AIC was used to adjust fit of the top selected models (Burnham and Anderson, 2002):

$$\text{QAIC}_c = \frac{-2\ln(L)}{\hat{c}} + 2K + \frac{2K(K+1)}{N-K-1}$$

To quantify the differences in support between models an index using normalized Akaike weights (*w*) was also calculated for each model (*i*) (Buckland et al., 1997):

$$w_i = \frac{e^{\frac{-\Delta QAIC_i}{2}}}{\sum e^{\frac{-\Delta QAIC_i}{2}}}$$

Results and Conclusion

The general model fit the data well (c = 1.55) and returned the lowest AIC value with the majority of support (0.98) among models (Table 3). Residuals for all models did not show any remarkable patterns (Figure 1). For the general model the terminal year Fs for each cohort had to be fixed to achieve convergence and realistic estimates for all *F*s. The values were fixed to the estimates derived from the cohort dependent parameterization. The need to fix these parameters suggests there was not enough information in the data to estimate an *F* for each cohort/year combination.

Estimates of M were similar across models, ranging from 0.30 to 0.35 (Table 3). The model with cohort dependent parameters, which converged without the need to fix parameters, returned an M of 0.30 and Fs equal to 0.17, 0.21, 0.36, 0.24, and 0.32 for cohorts 1 through 5, respectively.

It should be emphasized that these models assumed full reporting and no tag loss. Any violation of either assumption would lead to higher estimates for M. The estimated values of M should be viewed as a minimum. This short analysis of historical tagging data confirms that *M* for winter flounder is likely higher than 0.2 and an increase in *M* should be considered for assessment purposes.

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Table 1. Winter flounder tag-recovery data from Howe and Coates (1975).

Release	Releases	Recaptures				
Cohort	1964	1964	1965	1966	1967	1968
1. Tarpaulin Cove, Menemsha	500	72	43	28	7	5
2. Hedge Fence Shoal	500	92	45	32	11	2
3. Tuckernuck Shoal	498	132	63	44	13	7
4. Great Point, Nantucket	456	102	38	18	15	13
5. Rodgers Shoal	500	102	64	47	47	12

Table 2. Expected recoveries from four different model structures fit to winter flounder tagging data from Howe and Coates (1975). Parameters are specified in terms of survival (S) and recovery rate (f) for clarity.

Cohort	Year				
	1964	1965	1966	1967	1968
	1. Constant rate model (parameters: F, and M)				
1	$N_1 f$	$N_2 Sf$	$N_3 SSf$	$N_4 SSSf$	$N_5 SSSSf$
2	$N_6 f$	$N_7 Sf$	$N_8 SSf$	$N_9 SSSf$	$N_{10} SSSSf$
3	$N_{11} f$	$N_{12} Sf$	$N_{13} SSf$	$N_{14} SSSf$	$N_{15} SSSSf$
4	$N_{16} f$	$N_{17} Sf$	$N_{18} SSf$	$N_{19} SSSf$	$N_{20} SSSSf$
5	$N_{21} f$	$N_{22} Sf$	$N_{23} SSf$	$N_{24} SSSf$	$N_{25} SSSSf$
	2. Cohort dependent (parameters: F_c for c = 1, 2, 3, 4, 5, and M)				
1	$N_1 f_1$	$N_2 S_1 f_1$	$N_3 S_1 S_1 f_1$	$N_4 S_1 S_1 S_1 f_1$	$N_5 S_1 S_1 S_1 S_1 f_1$
2	$N_6 f_2$	$N_7 S_2 f_2$	$N_8 S_2 S_2 f_2$	$N_9 S_2 S_2 S_2 f_2$	$N_{10} S_2 S_2 S_2 S_2 f_2$
3	$N_{11} f_3$	$N_{12} S_3 f_3$	$N_{13} S_3 S_3 f_3$	$N_{14} S_3 S_3 S_3 f_3$	$N_{15} S_3 S_3 S_3 S_3 f_3$
4	$N_{16} f_4$	$N_{17} S_4 f_4$	$N_{18} S_4 S_4 f_4$	$N_{19} S_4 S_4 S_4 f_4$	$N_{20} S_4 S_4 S_4 S_4 f_4$
5	$N_{21} f_5$	$N_{22} S_5 f_5$	$N_{23} S_5 S_5 f_5$	$N_{24} S_5 S_5 S_5 f_5$	$N_{25} S_5 S_5 S_5 S_5 f_5$
	3. Year dependent (parameters: F_t for t = 1, 2, 3, 4, 5, and M)				
1	$N_1 f_1$	$N_2 S_1 f_2$	$N_3 S_1 S_2 f_3$	$N_4 S_1 S_2 S_3 f_4$	$N_5 S_1 S_2 S_3 S_4 f_5$
2	$N_6 f_1$	$N_7 S_1 f_2$	$N_8 S_1 S_2 f_3$	$N_9 S_1 S_2 S_3 f_4$	$N_{10} S_1 S_2 S_3 S_4 f_5$
3	$N_{11} f_1$	$N_{12} S_1 f_2$	$N_{13} S_1 S_2 f_3$	$N_{14} S_1 S_2 S_3 f_4$	$N_{15} S_1 S_2 S_3 S_4 f_5$
4	$N_{16} f_1$	$N_{17} S_1 f_2$	$N_{18} S_1 S_2 f_3$	$N_{19} S_1 S_2 S_3 f_4$	$N_{20} S_1 S_2 S_3 S_4 f_5$
5	$N_{21} f_1$	$N_{22} S_1 f_2$	$N_{23} S_1 S_2 f_3$	$N_{24} S_1 S_2 S_3 f_4$	$N_{25} S_1 S_2 S_3 S_4 f_5$
	4. Cohort and year dependent (parameters: F_{ct} for t = 1, 2, 3, 4, 5, c = 1, 2, 3, 4, 5 and M)				
1	$N_1 f_1$	$N_2 S_1 f_2$	$N_3 S_1 S_2 f_3$	$N_4 S_1 S_2 S_3 f_4$	$N_5 S_1 S_2 S_3 S_4 f_5$
2	$N_6 f_6$	$N_7 S_6 f_7$	$N_8 S_6 S_7 f_8$	$N_9 S_6 S_7 S_8 f_9$	$N_{10} S_6 S_7 S_8 S_9 f_{10}$
3	$N_{11} f_{11}$	$N_{12} S_{11} f_{12}$	$N_{13} S_{11} S_{12} f_{13}$	$N_{14} S_{11} S_{12} S_{13} f_{14}$	$N_{15} S_{11} S_{12} S_{13} S_{14} f_{15}$
4	$N_{16} f_{16}$	$N_{17} S_{16} f_{17}$	$N_{18} S_{16} S_{17} f_{18}$	$N_{19} S_{16} S_{17} S_{18} f_{19}$	$N_{20} S_{16} S_{17} S_{18} S_{19} f_{20}$
5	$N_{21} f_{21}$	$N_{22} S_{21} f_{22}$	$N_{23} S_{21} S_{22} f_{23}$	$N_{24} S_{21} S_{22} S_{23} f_{24}$	$N_{25} S_{21} S_{22} S_{23} S_{24} f_{25}$

Table 3. Model diagnostics and ranks from four instantaneous rates model fit to winter flounder tag-recovery data from Howe and Coates (1975). Adjustments were made based on a c-hat for the general model of 1.55.

Model	QAIC	Delta QAIC	QAIC weight	# of Parameters	QDeviance	M estimate
M(.) *F*(Cohort * t)	3930.48	0	0.98	21	21.73	0.31
M(.) *F*(Cohort)	3938.35	7.88	0.02	6	90.28	0.30
M(.) *F*(.)	3969.68	39.21	0	2	155.49	0.32
M(.) *F*(t)	3973.99	43.52	0	6	145.96	0.35

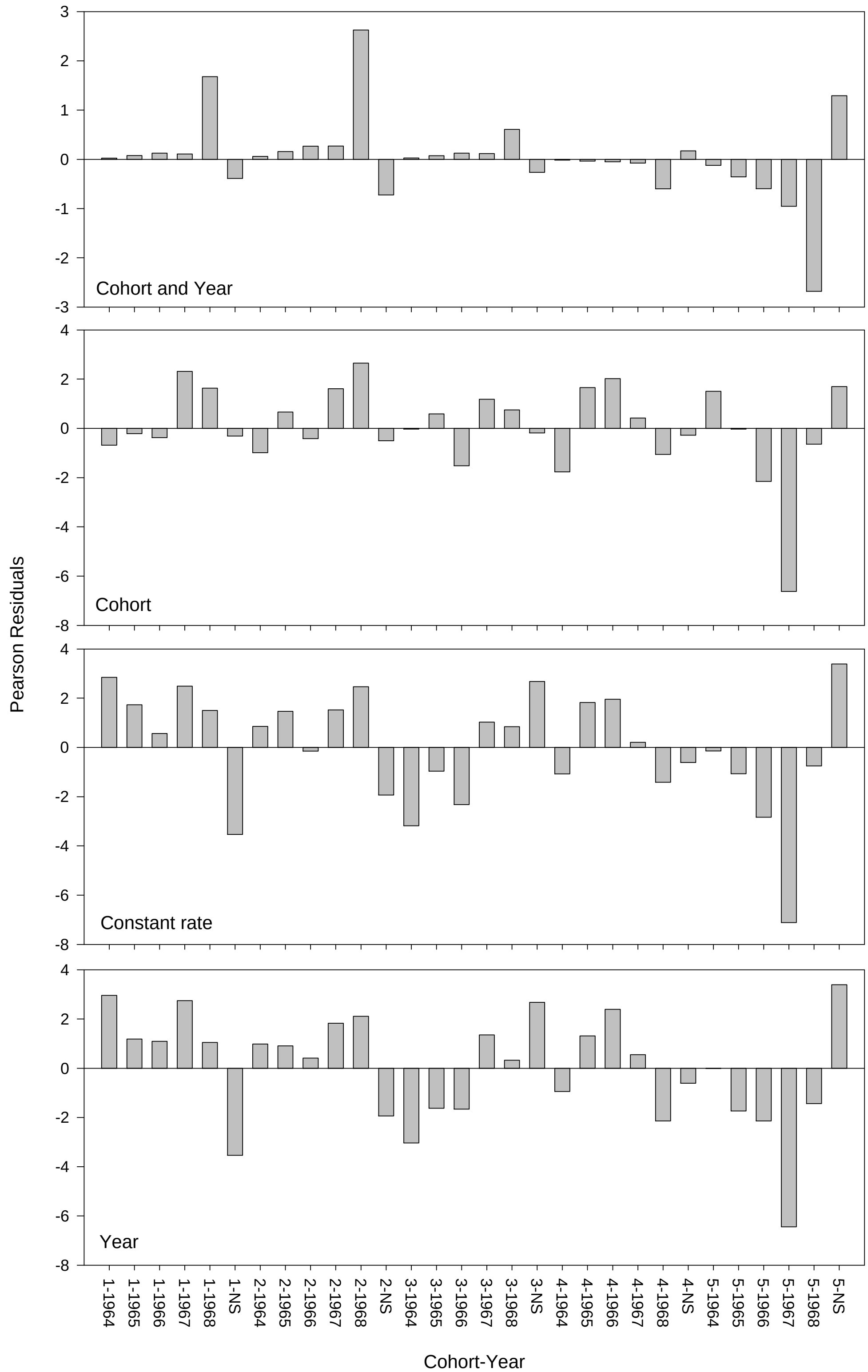

Figure 1. Pearson residuals from four instantaneous rates models fit to winter flounder data from Howe and Coates (1975). NS residuals are from probabilities relating to tags in a cohort that were never seen.

SDWG Background WP_D_16
May 2011
BRPs Vulnerability

D. SDWG52 Consensus Statement on Biological Reference Points (Term of Reference 6) and Vulnerability (Term of Reference 8b) for Winter Flounder Stocks

Term of Reference 6. *State the existing stock status definitions for "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; point estimates or proxies for BMSY, BTHRESHOLD, and FMSY) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.*

In addition to the stock-specific results, the SDWG developed a consensus response to TOR6, taking into consideration the assessment results for all three stocks. The fishing mortality and biomass Biological Reference Points (BRPs) discussed below are from the Final models accepted for the stocks. As defined in the Magnuson Act, 'overfishing' means "a rate or level of fishing mortality that jeopardizes the capacity of a fishery to produce the maximum sustainable yield on a continuing basis" (i.e., FMSY). The guidelines allow for the projected catch associated with the overfishing limit (OFL) to be based on FSMY proxies. Many proxies are used to define overfishing in situations when FMSY is not well determined. The SDWG interpreted these guidelines to mean that best practice is to use a FMSY estimate instead of a proxy when FSMY can be reliably estimated. The SDWG estimated FSMY for the winter flounder stocks as well as proxies in the form of F40%. The SDWG developed consensus on some aspects of the FMSY estimates (relative magnitude across stocks), but also had some disagreement about the reliability of FMSY estimates (related to the perceived reliability of the respective assessments). The SDWG could not come to consensus on the preferred reference points for the three winter flounder stocks. Updated estimates of F40% were provided as the existing overfishing definitions and as alternatives to FMSY and SSBMSY estimates. Estimates of F40% and SSB40% were provided as potential overfishing definitions based on the precedence offered by GARM3 (NEFSC 2008), instead of other potential Percent Maximum Spawning Potential (%MSP) alternatives.

Appropriateness of FMSY Estimates

The SDWG estimates of FMSY utilize data and prior information in a statistical framework. Estimation of the steepness parameters (*h*) in the stock-recruitment relationships used the available stock-recruitment estimates and a prior distribution of *h* from other Pleuronectid flatfishes (Myers et al. 1999), as was used in previous assessments of SNE/MA winter flounder (NEFSC 2002).

Steepness was estimated to be:

- 0.84 for Gulf of Maine winter flounder
- 0.85 for Georges Bank winter flounder
- 0.64 for SNE/MA winter flounder

The SDWG estimates of *h* for winter flounder stocks are realistic. They are compatible with both the estimates of *h* for Pleuronectids that were used as priors, and with the distribution of all of the estimates in Myers et al. (1999). Uncertainty in FMSY is estimable based on stock-recruitment relationships, but not all sources of uncertainty are included in the SDWG evaluation (e.g., uncertainty in assumed natural mortality, precision and accuracy of stock-recruit estimates are not considered).

Concerns about the reliability of the estimates FMSY

There are aspects of using a prior for steepness for these stocks that are problematic. If no prior is applied, two of the three resulting stock-recruit relationships are not theoretically feasible (e.g., the linear increase in SNE/MA recruitment as a function of spawning stock size; the constant recruitment even at low spawning stock size for GBK winter flounder). There are several concerns with the prior on *h* from Myers et al. (1999) meta-analysis for Pleurinectid flatfishes. The prior is not well understood, because the original data was not available at the SDWG. Many of the stocks used to form the prior have M < 0.2. The appropriateness of this prior for the U.S. winter flounder stocks, with assumed M = 0.3, is therefore unknown. The number of Pleuronectid stocks in the Myers et al. (1999) study is limited (n=14), and there were no winter flounder stocks included. Derivation of the precision estimate of *h* (0.09; NEFSC 2002) is not clearly documented. The assumed normal error structure for the prior may not be appropriate for a parameter bounded by 0.2 and 1. Myers et al. (1999) stated that "the family-level estimates (shown in boldface) should be used with caution." FMSY estimates depend on both mean and precision of steepness, but the SDWG did not have information on how well the Myers et al. (1999) values were estimated.

The precision of steepness (*h*) estimates show a moderate range of possible values and an associated moderate range in the estimates of FMSY (see text table below):

Estimates of steepness (h), FMSY and %MSP with 80% confidence intervals and CVs.

Stock	h	CV	10%	90%	FMSY	CV	10%	90%	%MSP	10%	90%
GOM	0.84	0.08	0.75	0.92	0.565	0.19	0.43	0.77	28	34	21
GBK	0.85	0.08	0.75	0.94	0.500	0.22	0.39	0.69	29	35	22
SNE/MA	0.64	0.08	0.57	0.76	0.310	0.07	0.27	0.43	42	46	32

The implied maximum lifetime reproductive rate [4*h*/(1-*h*)] is quite variable among the stock (*h*=0.64 implies *ahat*=7.1 while *h*=0.85 implies *ahat*=22.7), where *ahat* represents the number of spawners produced by each spawner over its lifetime at very low spawner abundance (i.e., assuming absolutely no density dependence). With similar growth, maturity and natural mortality rates, it is not clear why the implied reproductive rates are so different.

The %MSP associated with the range of FMSY estimates suggests that F40% is compatible with FMSY for SNE/MA winter flounder, but those ranges suggest that F40% is not compatible with FMSY for the GOM and GBK stocks. The %MSP associated with FMSY estimates range from 28% to 42%, but it is again unclear why the %MSP values are up to 50% different for stocks with similar biology and fishery characteristic, when only the stock-recruitment steepness differs.

The SDWG had several concerns about the use of F40% as an overfishing definition. F%MSP ignores any information from stock and recruitment estimates, and therefore may be inconsistent with FMSY estimates that use such information. The performance of F40% for achieving MSY has not been evaluated specifically for winter flounder stocks. The SDWG recognized the logical difference between "data-based" inferences involved in estimates of FMSY vs. “hypothesis-based” expectations of inter-stock similarities based on analogy to justify F40%.

In summary, from a comparative approach to MSY reference points, F40% is similar for all three stocks. The estimate of FMSY for GOM winter flounder is similar to that for the GBK stock but 60% higher than that for the SNE/MA stock. This range in FMSY among the three stocks is due to the differing patterns in the estimated stock-recruitment data (see text table below). The SNE/MA stock has a low steepness estimate that is driven by estimates of strong recruitment and high spawning stock size from the 1980s. Unlike the situation for SNE/MA winter flounder, for GOM and GBK winter flounder there is no pattern in the stock-recruitment estimates that supports inferences of lower steepness. The influences of environmental conditions that limit recruitment success (e.g., warmer temperatures and subsequent larval predation effects) are possible explanations of the lower steepness of the SNE/MA stock (and subsequently lower FMSY). The SDWG noted that these explanations assume no local and complete adaptation to environmental conditions among the stocks.

Stock	$\mathbf{F_{MSY}}$	**h**	$\mathbf{SSB_{MSY}}$	$\mathbf{SSB_0}$	$\mathbf{SSB_0/SSB_{MSY}}$	**MSY**	$\mathbf{F_{40}}$	$\mathbf{SSB_{40}}$	$\mathbf{MSY_{40}}$
GOM	0.565	0.84	2,167	8,887	4.10	1,152	0.340	3,287	1,080
GBK	0.500	0.85	8,260	31,478	3.81	4,200	0.320	11,300	3,200
SNE/MA	0.310	0.64	33,820	92,657	2.74	9,763	0.327	29,045	8,903

Implications of Reference Point Decisions

Despite the uncertainty in reference point estimation for SNE/MA Atlantic winter flounder, the determination of stock status and rebuilding conclusions are robust. All candidate reference points lead to a conclusion that the stock cannot rebuild to SSBMSY by 2014, even at F = 0.

Major uncertainty persists in the GOM winter flounder stock assessment, and estimates of current biomass are much greater than all candidate estimates of BSMY or BMSY proxies. However, the relatively low estimates of F and conclusion that overfishing is not occurring are consistent with recent regulations and restrictions on catch. The estimate of SSBMSY corresponding to h = 0.84 for GOM winter flounder is close to the lower end of the range of past SSB estimates, in contrast to the situation for GBK winter flounder, where it is close to the middle of this range. The minimum observed GOM SSB was 1,487 mt, and the 80% confidence interval of SSBMSY is 1,640 to 2,700 mt. Although the 80% confidence intervals for h for each of these two stocks are similar, this feature of the GOM estimates renders them less reliable than those for the GBK stock. While there were disagreements within the SDWG on the BRPs to use as the overfishing definition, the SDWG reached consensus that the current model and associated reference points for GOM winter flounder were acceptable and the best that could be determined at this time.

Term of Reference 8b. "*Take into consideration uncertainties in the assessment and the species biology to describe this stock's vulnerability (see "Appendix to the SAW TORs") to becoming or remaining overfished, and how this could affect the choice of ABC.*"

Appendix to the SAW Terms of Reference: "*Vulnerability. A stock's vulnerability is a combination of its productivity, which depends upon its life history characteristics, and its susceptibility to the fishery. Productivity refers to the capacity of the stock to produce MSY and to recover if the population is depleted, and susceptibility is the potential for the stock to be impacted by the fishery, which includes direct captures, as well as indirect impacts to the fishery (e.g., loss of habitat quality).*"

The Working Group accounted for vulnerability, productivity and susceptibility using conventional MSY reference points, and evaluated uncertainty using model estimates of precision and qualification of other uncertainties. Age-based analytical stock assessment models and associated MSY reference point evaluations provide a relatively comprehensive and synthetic evaluation of vulnerability that is consistent with stock status determination and projection. Vulnerability and susceptibility were accounted for in both aspects of status determination (estimation of F and FMSY) and projections as the magnitude of fishing mortality and recent fishery selectivity at age. All components of productivity (reproduction, individual growth, and survival) were also explicitly accounted for in stock status determination and projections. Reproduction was monitored as age-1 recruitment, and projected as a function of SSB (the product of abundance, weight and maturity at age). Individual growth was monitored as empirical size at age, and projected as recent mean size at age. Survival was accounted for based on model estimates of fishing mortality and selectivity as well as assumed natural mortality, which was informed by tagging analysis.

Uncertainties that were not accounted for by assessment and reference point models were evaluated using model diagnostics. Standard model diagnostics (e.g., residual analyses, retrospective analyses) were used for model validation. Retrospective inconsistencies that were outside the bounds of model precision estimates were addressed through selection of alternative models.

Vulnerabilities that were not accounted for by assessment and reference point models were evaluated using exploratory modeling, habitat observations and testing the influence of environmental factors on recruitment dynamics. All three winter flounder stocks are harvested in mixed-stock fisheries, but bycatch and discards are monitored and managed through Annual Catch Limits with Accountability Measures for exceeding those limits.

Additional considerations of vulnerability and productivity are the implications of shifts in distribution, recruitment dynamics and increased natural mortality. Nye et al. (2009) found an annual increase in mean depth (0.8 m per year) of the winter flounder distribution over the NEFSC survey time series from 1968-2007, which may have productivity and vulnerability implications. Apparent decreases in estuarine spawning or shifts toward coastal spawning (e.g., DeCelles and Cadrin 2010) may also have implications for vulnerability (e.g., less availability to recreational fisheries) and productivity (less larval retention). Consumption of winter flounder by other fishes, birds and mammals may be increasing as these predator populations increase.

A considerable source of additional vulnerability is the continued weak recruitment and low reproductive rate (e.g., recruits per spawners) of Southern New England/Mid Atlantic (SNE/MA) winter flounder. If weak recruitment and low reproductive rate continues, productivity and rebuilding of SNE/MA winter flounder will be less than projected. Stock-recruit modeling suggests that warm temperatures are having a negative effect on recruitment of SNE/MA winter flounder.

The GOM assessment indicates that the stock is well above BMSY and experiencing very low fishing mortality. However, the GOM assessment is the most uncertain of the three (from a "feasibility" perspective, if not from a "statistical precision" perspective). Therefore, it may be vulnerable to overfishing if managed at a catch level close to the nominally projected catch in the near term.

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Initial Applications of Statistical Catch-at-Age Assessment Methodology to the Southern New England/Mid-Atlantic Winter Flounder Resource

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Abstract

SCAA is applied to the SNE winter flounder resource, for which past VPA assessments have been plagued by retrospective patterns. It is shown that these patterns can be removed by the combination of allowance for autocorrelation in the residuals of survey series fits to underlying abundance trends, and an increase in natural mortality over time commencing sometime during the 1990s.

Introduction

This paper presents the results of some initial applications of Statistical Catch-at-Age methodology to data for the Southern New England/Mid-Atlantic winter flounder resource. This exercise has focused on attempts to remove the retrospective pattern evident in past assessments, which has been reduced though not eliminated by the approach of allowing an estimable change in survey catchability *q* between 1993 and 1994 (Terceiro, 2008).

Data and Methodology

The catch and survey based data (including catch-at-age information) and some biological data are listed in Tables in Appendix A. They are as kindly provided by Mark Terceiro on 17 March. The aim of the paper is primarily methodological, and the work was carried out before subsequent updates to these data became available. The key run will be repeated with these updated data and the results presented in a subsequent document.

The details of the SCAA assessment methodology are provided in Appendix B.

Various approaches were attempted to remove the retrospective pattern which occurs in this assessment as for earlier VPAs (Terceiro, 2008). These included adding auto-correlation to the recruitment time series, which proved unsuccessful. The most successful approach was found to be the combination of allowing estimable auto-correlation in the residuals about the fits to each survey index and an increase in natural mortality over recent years, where best results were found to be provided by having this increase occur smoothly from M=0.3 prior to 1995 to 0.6 by 2005 and thereafter (the higher value was estimated in the model fit, subject to an upper bound of 0.6).

Results are illustrated in terms of three Base Cases, with the following characteristics:

	Base Case 1 (BC1)	Base Case 2 (BC2)	Base Case 3 (New Base Case, NBC)
Survey indices	split in 1993/1994, different q's estimated for the two periods but same selectivity	Not split	Not split
First order autocorrelation in the surveys	No	Estimated for each survey index	Estimated for each survey index
Natural mortality	0.2 throughout	0.2 throughout	0.3 pre-1995, linear increase from 0.3 in 1995 to 0.6* in 2005, 0.6* thereafter
Commercial selectivity	two periods: 1981-1993, 1994-2010	two periods: 1981-1993, 1994-2010	two periods: 1981-1993, 1994-2010
Starts in	1981	1981	1981

* Estimate hit upper bound

A series of variants of the NBC are also considered.

Results and Discussion

Results for the three Base Cases are given in Table 1. Retrospective patterns for spawning biomass and recruitment trajectories are compared in Fig. 1 for each of the three Base Cases. A full set of results are shown for the New Base Case in Figs 2-6, which show the estimated spawning biomass trend, the stock-recruitment relationship and residuals, the selectivity-at-age vectors, and the model fits to data for the survey indices of abundance and the various sources of proportions-at-age information. Fig. 7 plots the biomass loss to the increase in *M* in the NBC.

Tables 2 and 3 give results for variants to the NBC, with retrospective patterns plotted in Fig. 8 and the spawning biomass trajectories for variant 8 (starting in 1964) plotted in Fig. 9.

Results shown in Table 1 (Mohn's ρ) and in Fig. 1 show that the NBC approach of allowing for autocorrelation in the residuals for the survey indices, and for natural mortality to increase after 1995, effectively removes the retrospective pattern in this assessment.

The reason the autocorrelation (which of itself does little to remove this pattern) is required is evident from inspection of Fig. 5. Fig. 5a shows that with the surveys split in 1993/1994, the NEFSC fall survey fits the survey trend reasonably. However if the split is removed (Fig. 5b) the fit appears very poor, with clear systematic trends in residuals (Fig. 5b). If autocorrelation is taken into account though, the associated residuals no longer show these systematic trends, both in Fig. 5b and for the NBC in Fig. 5c. Hypothesising such auto-correlation is not unreasonable, as the environmental effects responsible for the fluctuations in survey *q* over time could well have some persistence and hence show positive autocorrelation. CAA residuals for the NBC (Fig. 6) appear acceptable.

Table 1 also shows that for the NBC, the variability in recruitment is more consistent over time (similar values of σ_R_out for earlier and later periods unlike for BC1 or BC2.

Table 2 compares results for different input values for natural mortality *M* and its changes over time. In log likelihood terms, the only (slight) improvement compared to the NBC is through commencing the increase in *M* in 1990 rather than 1995. Results in Table 3 show that replacing estimation of a separate autocorrelation parameter for each survey by a single estimable parameter is marginally preferable in AIC terms, but makes little difference to key results. Retrospective patterns are all minimal for these further scenarios (see Mohn's ρ values in Tables 2 and 3, and Fig. 8).

Fig. 2 compares the NBC estimate of the spawning biomass trajectory with that from the previous GARM assessment as provided by VPA. The trends are very similar, with the differences in scale attributable primarily for the higher (initial) M value of 0.3 for the NBC compared to 0.2 for that VPA.

Fig. 7 reports the additional loss of flounder to natural mortality arising from the increase in M over time for the NBC. Note that the assessment results would be essentially unchanged if this reflected catches not taken into account rather than additional natural predation.

Fig. 9 reports results of starting the assessment in 1964 rather than 1981. This requires assumptions to develop the total catch made over that period, which are detailed in Appendix A. Because no catch-at-age data are available for that period, there is no basis to estimate recruitment residuals, so a constant recruitment level is assumed. These results suggest that the peak in spawning biomass in about 1980 initiated as a result of reduction of catches in the 1970's, and was reversed by an increase in those catches in the 1980s, rather than reflecting a period of enhanced reproduction during favourable environmental conditions.

In summary, the adjustment of the assessment to include autocorrelation in the residuals of survey indices as measures of abundance, together with an increase in M over time initiating sometime during the 1990s, can resolve the retrospective pattern observed in past assessments of this resource. Ready biological justification is available for the introduction of the first of these features, but it is more difficult to suggest mechanisms to explain the second.

Further Work Planned

The New Base Case reported here will be updated given updated data.

Reference

Terceiro M. 2008. J. Southern New England/Mid-Atlantic winter flounder. Appendix to the Report of the 3rd Groundfish Assessment Review Meeting (GARM III): Assessment of 19 Northeast Groundfish Stocks through 2007, Northeast Fisheries Science Center, Woods Hole, Massachusetts, August 4-8, 2008 http://www.nefsc.noaa.gov/publications/crd/crd0816/pdfs/garm3j.pdf

Table 1: Results for the three Base Cases. Biomass units are '000t. The two recruitment values refer to the averages over two recruitment periods, i.e. 1989-2010 and 1981-1988 respectively. MSY and related quantities have been computed under each of these recruitment levels, assuming the natural mortality *M* that applies in the most recent year if *M* is taken to have changed over time. Further details regarding some of the quantities shown can be found in Appendix B, section B.3.2.

	Base Case 1						Base Case 2				New Base Case			
'-lnL:overall	-763.2						-798.7				-864.1			
'-lnL:Survey	-27.5						-37.2				-49.8			
'-lnL:CAA	-90.3						-92.8				-91.7			
'-lnL:CAAsurv	-640.9						-662.0				-701.7			
'-lnL:RecRes	-5.7						-7.9				-21.9			
'-lnL:SelSmoothing	1.1						1.1				0.9			
Mohn's rho: SSB	0.48						0.49				-0.03			
Mohn's rho: rec.	1.28						1.11				0.16			
Phi	0.59						0.85				0.83			
Bsp(1981)	20.8						19.5				20.8			
Bsp(2010)	5.0						6.4				4.1			
Bsp(2010)/Bsp(1981)	0.24						0.33				0.20			
M	0.20						0.20				0.3-0.6			
Recruitment	11.2	37.5					11.9	39.3			25.7	52.8		
Bsp(MSY)	4.6	15.5					5.2	17.1			2.0	4.1		
MSY	3.2	10.8					3.4	11.4			2.4	5.0		
σ_{comCAA}	0.10						0.10				0.10			
		first period			second period									
Survey	q x10^6	σ_{surv}	σ_{CAA}	q x10^6	σ_{surv}	σ_{CAA}	q x10^6	σ_{surv}	σ_{CAA}	ρ	q x10^6	σ_{surv}	σ_{CAA}	ρ
NEFSCspr	182.1	0.31	0.12	280.6	0.32	0.10	255.1	0.35	0.11	0.37	285.2	0.31	0.10	0.06
NEFSCfall	549.7	0.56	0.18	1790.5	0.54	0.13	1086.4	0.50	0.15	0.78	936.6	0.47	0.15	0.67
NEFSCwinter	364.7	0.41	0.20		-		358.9	0.34	0.20	0.48	233.5	0.30	0.19	0.21
MADFM	1.40	0.47	0.18	2.48	0.37	0.15	2.74	0.41	0.16	0.56	3.31	0.41	0.15	0.51
RIDFW	0.49	0.63	0.14	0.64	0.42	0.16	0.57	0.54	0.15	0.29	0.57	0.51	0.16	0.20
CTDEP	2.47	0.60	0.15	2.10	0.54	0.15	2.79	0.50	0.13	0.57	3.13	0.51	0.12	0.68
NY	0.23	0.73	0.08	0.23	0.90	0.25	0.21	0.86	0.19	0.03	0.11	0.92	0.20	0.28
NJDFW Ocean	3.23	0.46	0.16		-		4.22	0.44	0.16	0.02	4.13	0.42	0.16	-0.03
NJDFW River	0.32	0.22	0.18		-		0.42	0.23	0.18	0.23	0.39	0.27	0.18	0.58
MADFM YOY	0.01	0.51	-	0.02	0.61	-	0.01	0.48	-	0.66	0.01	0.44	-	0.50
CTDEP YOY	0.38	0.70	-	0.62	0.60	-	0.53	0.66	-	0.29	0.24	0.65	-	0.26
RIDFW YOY	0.96	0.59	-	1.08	1.09	-	1.00	0.74	-	0.62	0.48	0.71	-	0.52
NY YOY	0.36	1.61	-	0.25	1.26	-	0.28	1.30	-	0.44	0.14	1.33	-	0.60
DEDFW YOY	0.01	1.30	-	0.01	0.88	-	0.01	1.01	-	-0.24	0.00	1.00	-	-0.23
URIGSO	0.70	0.36	0.16	0.98	0.60	0.15	0.82	0.53	0.15	0.34	0.53	0.51	0.13	0.31
σ_R_out (81-88, 89-10)	0.28	0.46					0.27	0.43			0.27	0.26		

Table 2: Results for variants on the New Base Case relating to different specifications for *M* and its changes over time.

	New Base Case				Variant 1: M_{start}=0.2				Variant 2: M_{start}=0.4				Variant 3: *M* changes over 1995-2000				Variant 4: *M* changes over 1995-2010				Variant 5: *M* changes over 1990-2005				Variant 6: *M* changes over 2000-2010			
'-lnL:overall	-864.1				-863.6				-860.2				-856.9				-859.3				-867.4				-860.5			
'-lnL:Survey	-49.8				-48.9				-52.1				-49.7				-51.5				-52.5				-47.2			
'-lnL:CAA	-91.7				-91.5				-93.6				-91.8				-94.1				-91.5				-92.8			
'-lnL:CAAsurv	-701.7				-702.2				-694.0				-698.1				-692.9				-703.4				-698.5			
'-lnL:RecRes	-21.9				-22.0				-21.4				-18.3				-21.9				-20.9				-23.2			
'-lnL:SelSmoothing	0.9				1.0				0.9				1.0				1.1				0.9				1.0			
Mohn's rho: SSB	-0.03				-0.03				0.04				0.01				0.05				-0.01				-0.01			
Mohn's rho: rec.	0.16				0.13				0.31				0.27				0.32				0.24				0.15			
Phi	0.83				0.84				0.82				0.83				0.83				0.86				0.83			
Bsp(1981)	20.8				18.6				24.1				21.0				21.3				20.6				21.0			
Bsp(2010)	4.1				3.7				5.3				5.2				4.4				4.8				3.6			
Bsp(2010)/Bsp(1981)	0.20				0.20				0.22				0.25				0.21				0.23				0.17			
M	0.3-0.6				0.2-0.54				0.4-0.6				0.3-0.55				0.3-0.6				0.3-0.6				0.3-0.6			
Recruitment	25.7	52.8			19.0	39.8			32.2	70.9			27.7	52.7			22.7	52.7			29.9	53.0			21.7	52.7		
Bsp(MSY)	2.0	4.1			2.8	5.8			2.6	5.7			2.5	4.7			1.5	3.5			2.6	4.6			1.6	3.8		
MSY	2.4	5.0			1.8	3.8			3.0	6.6			3.0	5.7			2.2	5.2			2.7	4.8			2.1	5.1		
σ_{comCAA}	0.10				0.10				0.10				0.10				0.10				0.10				0.10			
Survey	q x10^6	σ_{surv}	σ_{CAA}	ρ	q x10^6	σ_{surv}	σ_{CAA}	ρ	q x10^6	σ_{surv}	σ_{CAA}	ρ	q x10^6	σ_{surv}	σ_{CAA}	ρ	q x10^6	σ_{surv}	σ_{CAA}	ρ	q x10^6	σ_{surv}	σ_{CAA}	ρ	q x10^6	σ_{surv}	σ_{CAA}	ρ
NEFSCspr	285.2	0.31	0.10	0.06	284.3	0.31	0.10	0.09	260.7	0.30	0.11	0.04	264.9	0.30	0.10	-0.01	250.2	0.31	0.11	0.08	299.7	0.30	0.10	0.03	288.9	0.33	0.10	0.21
NEFSCfall	936.6	0.47	0.15	0.67	1036.6	0.47	0.15	0.69	835.8	0.47	0.15	0.68	892.4	0.47	0.15	0.66	939.6	0.47	0.15	0.70	901.6	0.47	0.15	0.65	985.2	0.47	0.15	0.71
NEFSCwinter	233.5	0.30	0.19	0.21	269.5	0.30	0.19	0.21	211.2	0.30	0.19	0.24	223.7	0.30	0.19	0.23	250.5	0.30	0.19	0.23	217.4	0.31	0.19	0.26	256.6	0.31	0.19	0.29
MADFM	3.31	0.41	0.15	0.51	3.32	0.41	0.15	0.52	2.95	0.40	0.16	0.48	2.98	0.40	0.15	0.46	2.82	0.41	0.16	0.50	3.40	0.39	0.15	0.42	3.38	0.42	0.16	0.56
RIDFW	0.57	0.51	0.16	0.20	0.60	0.51	0.16	0.18	0.50	0.52	0.16	0.21	0.53	0.52	0.16	0.23	0.53	0.51	0.16	0.18	0.56	0.53	0.16	0.25	0.58	0.51	0.16	0.18
CTDEP	3.13	0.51	0.12	0.68	3.07	0.51	0.12	0.67	2.88	0.51	0.13	0.67	2.91	0.51	0.12	0.68	2.68	0.51	0.13	0.66	3.34	0.50	0.12	0.67	3.16	0.51	0.12	0.67
NY	0.11	0.92	0.20	0.28	0.15	0.92	0.21	0.29	0.09	0.90	0.20	0.21	0.11	0.91	0.20	0.26	0.13	0.91	0.20	0.21	0.10	0.89	0.20	0.21	0.13	0.92	0.20	0.28
NJDFW Ocean	4.13	0.42	0.16	-0.03	4.07	0.43	0.16	-0.02	3.85	0.41	0.16	-0.10	3.74	0.45	0.16	0.08	3.59	0.40	0.16	-0.13	4.34	0.42	0.16	-0.06	4.35	0.39	0.16	-0.18
NJDFW River	0.39	0.27	0.18	0.58	0.39	0.27	0.18	0.60	0.37	0.26	0.18	0.53	0.34	0.24	0.18	0.36	0.35	0.26	0.18	0.55	0.41	0.25	0.18	0.48	0.43	0.28	0.18	0.76
MADFM YOY	0.01	0.44	-	0.50	0.01	0.43	-	0.50	0.01	0.44	-	0.52	0.01	0.44	-	0.52	0.01	0.44	-	0.52	0.01	0.44	-	0.51	0.01	0.44	-	0.53
CTDEP YOY	0.24	0.65	-	0.26	0.33	0.65	-	0.28	0.20	0.64	-	0.21	0.23	0.63	-	0.18	0.28	0.64	-	0.24	0.21	0.63	-	0.15	0.29	0.66	-	0.33
RIDFW YOY	0.48	0.71	-	0.52	0.65	0.71	-	0.51	0.39	0.72	-	0.54	0.45	0.74	-	0.57	0.54	0.72	-	0.53	0.42	0.73	-	0.55	0.56	0.69	-	0.47
NY YOY	0.14	1.33	-	0.60	0.18	1.34	-	0.61	0.11	1.32	-	0.57	0.13	1.31	-	0.58	0.15	1.33	-	0.56	0.12	1.30	-	0.57	0.16	1.35	-	0.60
DEDFW YOY	0.00	1.00	-	-0.23	0.00	1.00	-	-0.23	0.00	0.98	-	-0.26	0.00	1.01	-	-0.21	0.00	0.98	-	-0.26	0.00	0.99	-	-0.25	0.00	0.98	-	-0.26
URIGSO	0.53	0.51	0.13	0.31	0.64	0.51	0.13	0.31	0.45	0.50	0.14	0.28	0.50	0.51	0.13	0.33	0.56	0.50	0.14	0.27	0.49	0.51	0.13	0.30	0.58	0.50	0.13	0.29
σ_R_out (81-88, 89-10)	0.27	0.26			0.26	0.26			0.28	0.27			0.27	0.32			0.27	0.26			0.27	0.28			0.27	0.24		

Table 3: Results for two further variants on the New Base Case.

	New Base Case				Variant 7: single ρ for surveys				Variant 8: start in 1960			
'-lnL:overall	-864.1				-851.1				-814.4			
'-lnL:Survey	-49.8				-36.9				-39.0			
'-lnL:CAA	-91.7				-91.8				-66.9			
'-lnL:CAAsurv	-701.7				-701.5				-688.9			
'-lnL:RecRes	-21.9				-21.9				-21.0			
'-lnL:SelSmoothing	0.9				0.9				1.4			
Mohn's rho: SSB	-0.03				-0.02				-0.03			
Mohn's rho: rec.	0.16				0.17				0.04			
Phi	0.83				0.83				0.83			
Bsp(1964)	-				-				9.40			
Bsp(1981)	20.8				20.8				34.5			
Bsp(2010)	4.1				4.1				4.9			
Bsp(2010)/Bsp(1981)	0.20				0.20				0.14			
M	0.3-0.6				0.60	0.60			0.60			
Recruitment	25.7	52.8			25.7	52.8			28.0	60.6		
Bsp(MSY)	2.0	4.1			2.0	4.1			1.8	3.9		
MSY	2.4	5.0			2.4	5.0			2.8	6.0		
σ_{comCAA}	0.10				0.10				0.11			
Survey	$q \times 10^6$	σ_{surv}	σ_{CAA}	ρ	$q \times 10^6$	σ_{surv}	σ_{CAA}	ρ	$q \times 10^6$	σ_{surv}	σ_{CAA}	ρ
NEFSCspr	285.2	0.31	0.10	0.06	279.7	0.32	0.10	0.40	146.0	0.49	0.11	0.37
NEFSCfall	936.6	0.47	0.15	0.67	934.9	0.50	0.15	0.40	803.6	0.49	0.16	0.76
NEFSCwinter	233.5	0.30	0.19	0.21	232.7	0.30	0.19	0.40	208.3	0.30	0.20	0.20
MADFM	3.31	0.41	0.15	0.51	3.22	0.41	0.15	0.40	0.89	0.41	0.15	0.49
RIDFW	0.57	0.51	0.16	0.20	0.56	0.52	0.16	0.40	0.41	0.53	0.16	0.25
CTDEP	3.13	0.51	0.12	0.68	3.03	0.54	0.12	0.40	1.51	0.51	0.12	0.71
NY	0.11	0.92	0.20	0.28	0.11	0.92	0.20	0.40	0.11	0.92	0.20	0.31
NJDFW Ocean	4.13	0.42	0.16	-0.03	3.98	0.46	0.16	0.40	1.53	0.43	0.16	-0.02
NJDFW River	0.39	0.27	0.18	0.58	0.37	0.27	0.18	0.40	0.14	0.27	0.18	0.58
MADFM YOY	0.01	0.44	-	0.50	0.01	0.44	-	0.40	0.01	0.44	-	0.52
CTDEP YOY	0.24	0.65	-	0.26	0.24	0.65	-	0.40	0.22	0.64	-	0.26
RIDFW YOY	0.48	0.71	-	0.52	0.48	0.72	-	0.40	0.45	0.72	-	0.54
NY YOY	0.14	1.33	-	0.60	0.14	1.36	-	0.40	0.13	1.33	-	0.61
DEDFW YOY	0.00	1.00	-	-0.23	0.00	1.18	-	0.40	0.00	1.00	-	-0.21
URIGSO	0.53	0.51	0.13	0.31	0.53	0.51	0.13	0.40	0.49	0.51	0.13	0.33
σ_R_out (81-88, 89-10)	0.27	0.26			0.27	0.26			0.29	0.28		

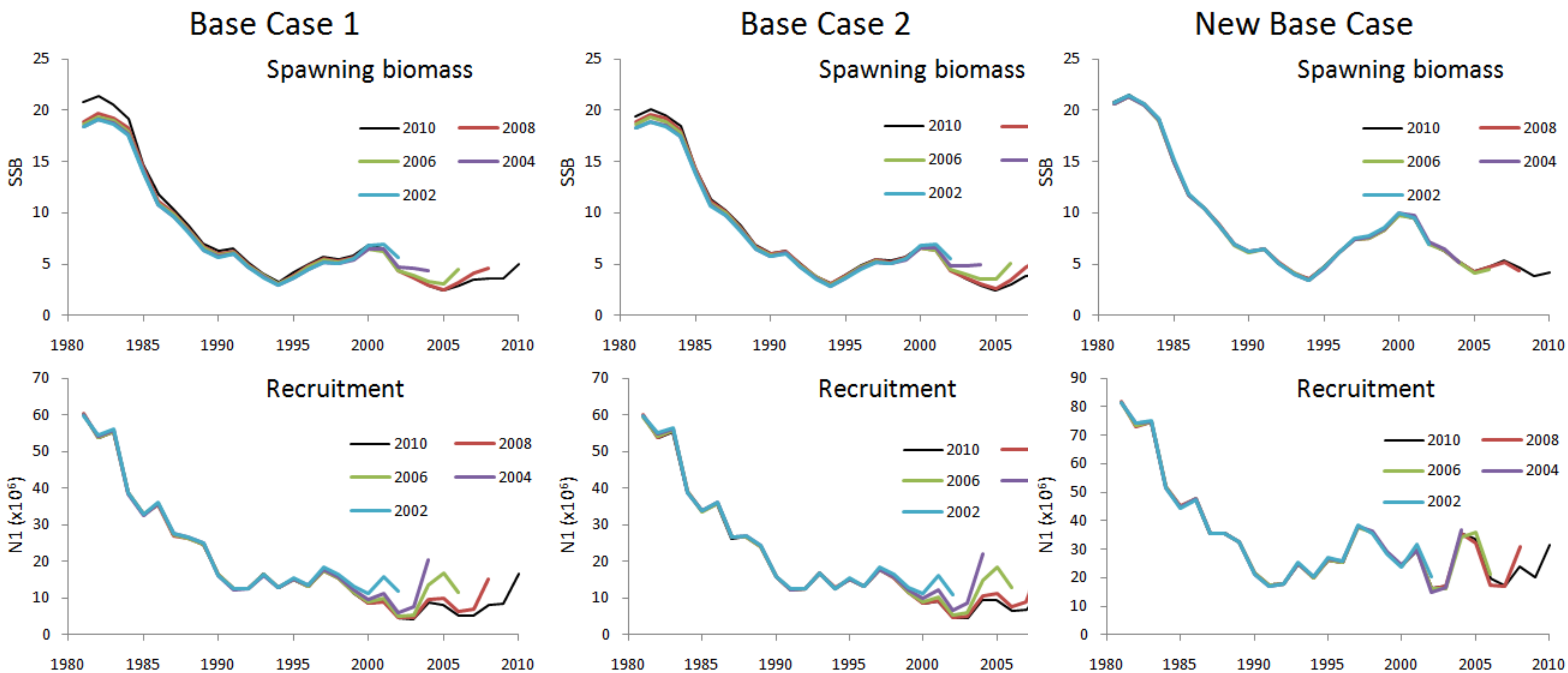

Fig. 1: Retrospective analysis of spawning biomass and recruitment for the three Base Cases.

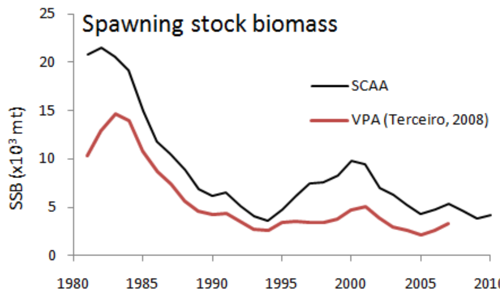

Fig. 2: Spawning stock biomass trajectories for the New Base Case, compared to the GARM3 SPLIT VPA run (Terceiro, 2008).

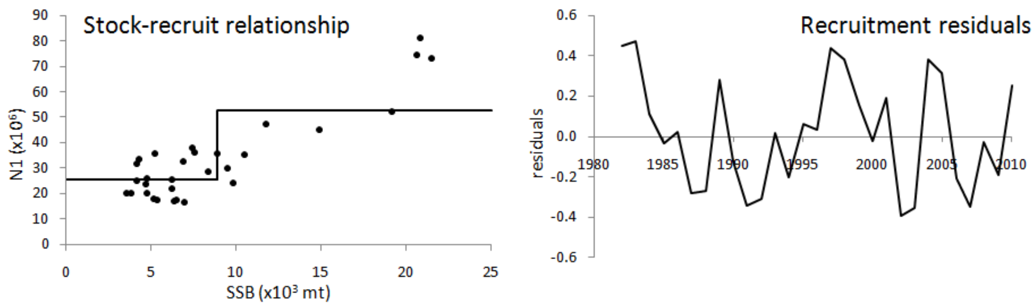

Fig. 3: Stock-recruit relationship and estimated stock-recruit residuals for the New Base Case. The change from high to lower recruitment is taken to occur at the minimum spawning biomass over the pre-1989 period.

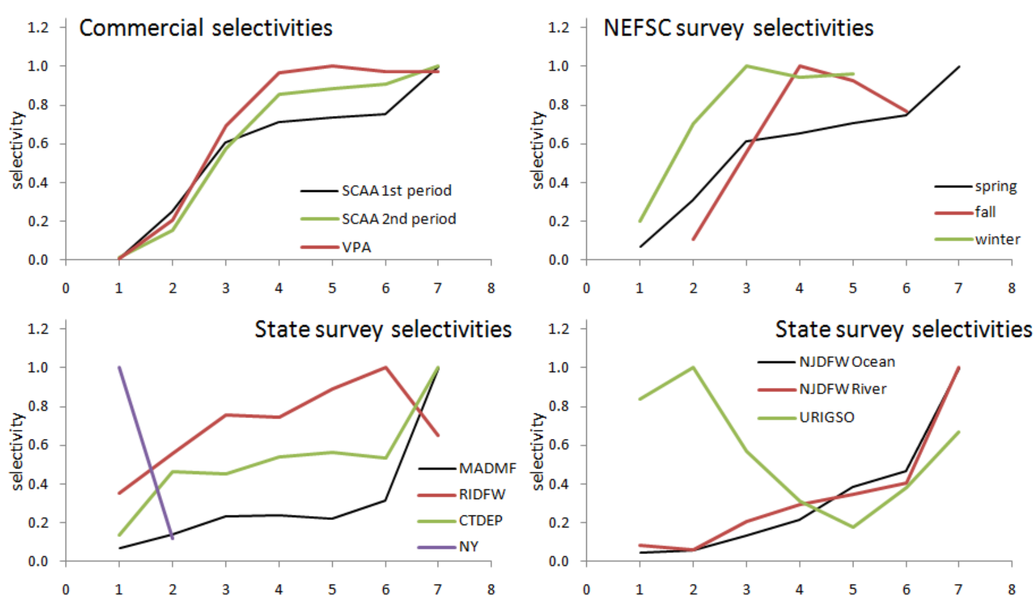

Fig. 4: Commercial and survey selectivities-at-age estimated for the New Base Case.

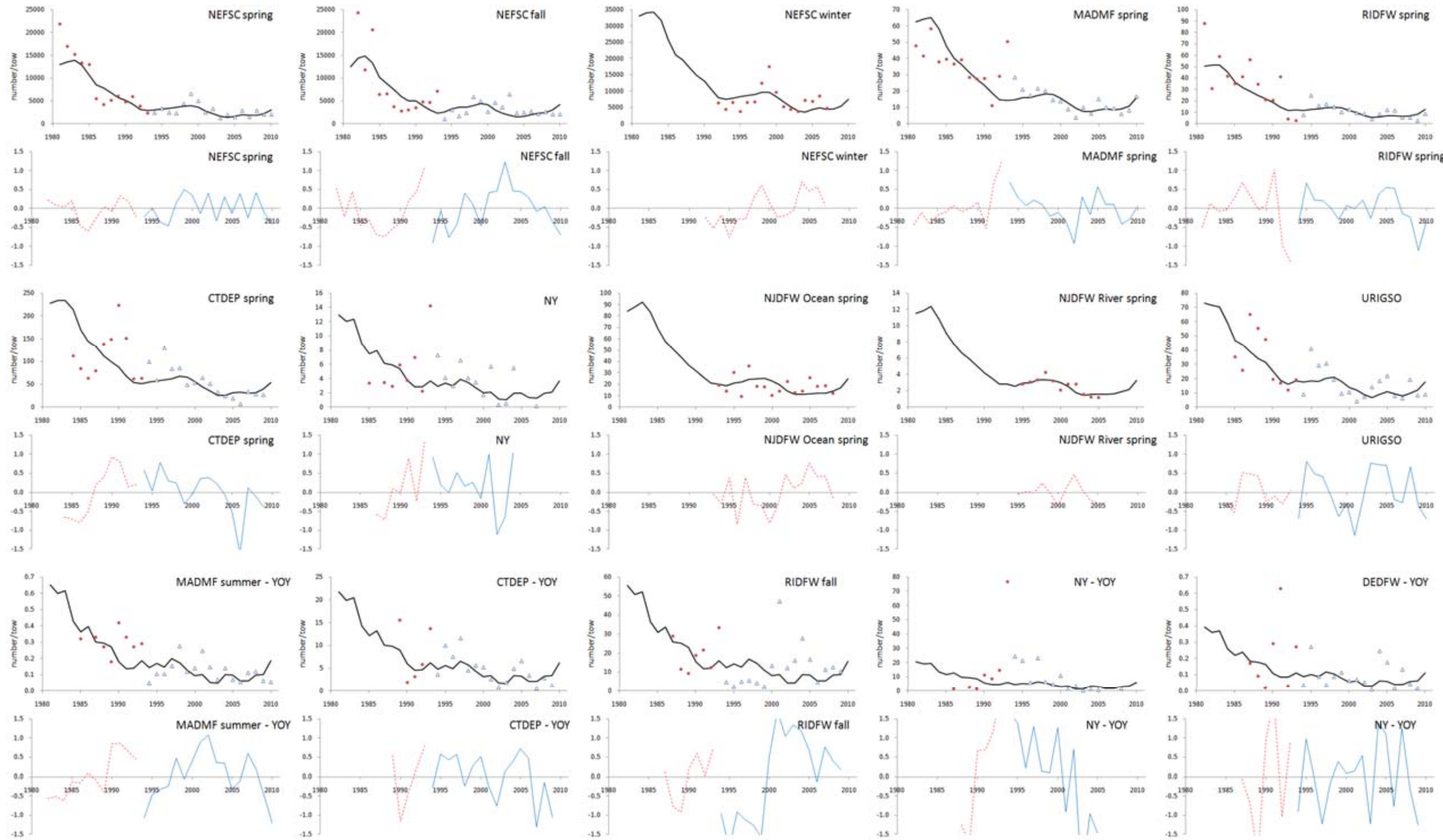

Fig. 5a: Fit of the Base Case 1 to the survey indices of abundance and corresponding survey standardised residuals. The survey data for the second period have been scaled by the ratio of the pre- and post-1993 indices *q*.

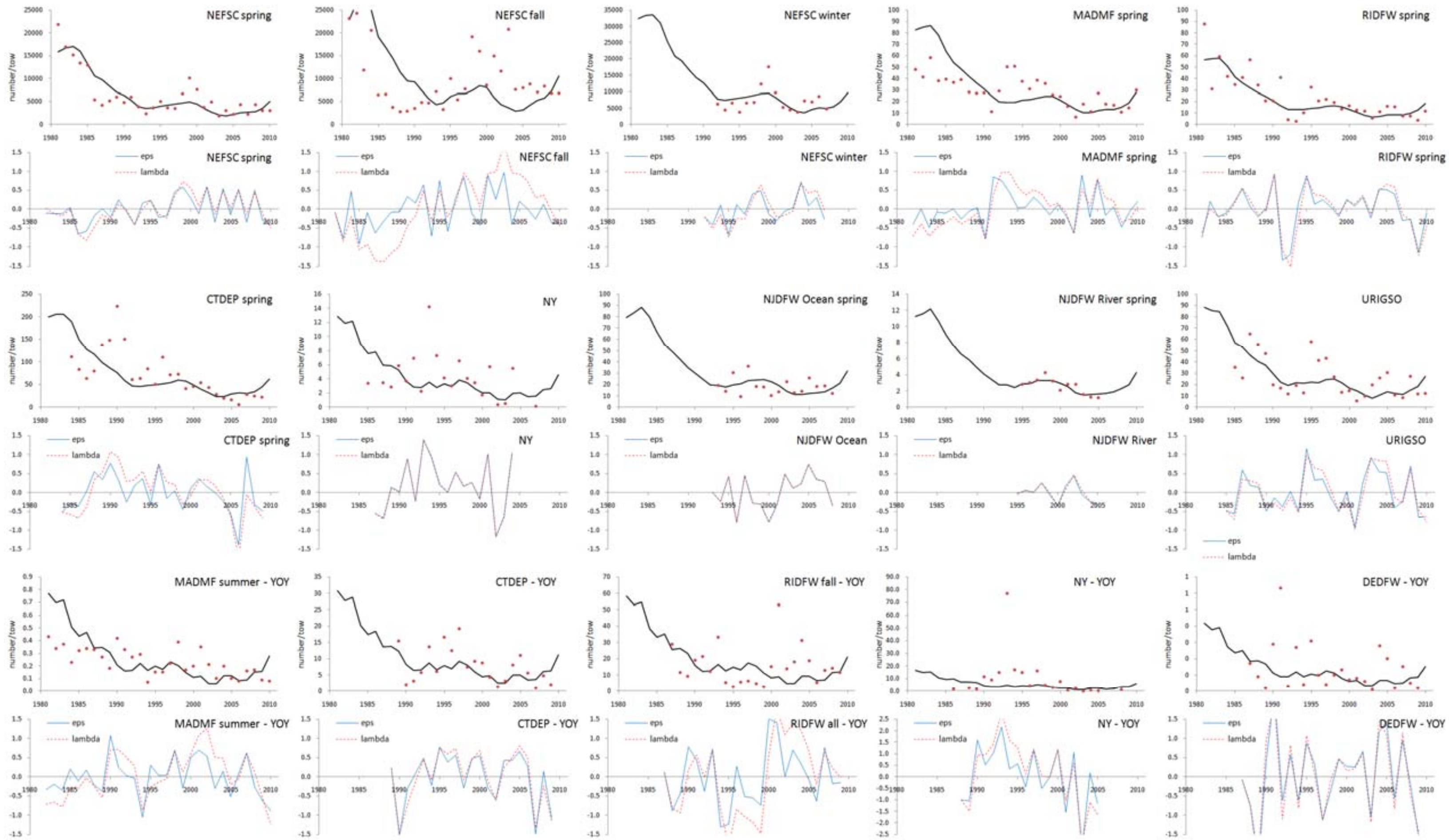

Fig. 5b: Fit of the Base Case 2 to the survey indices of abundance and corresponding survey standardised residuals. Residuals are shown both before ("lambda") and after ("eps") adjustment for serial correlation.

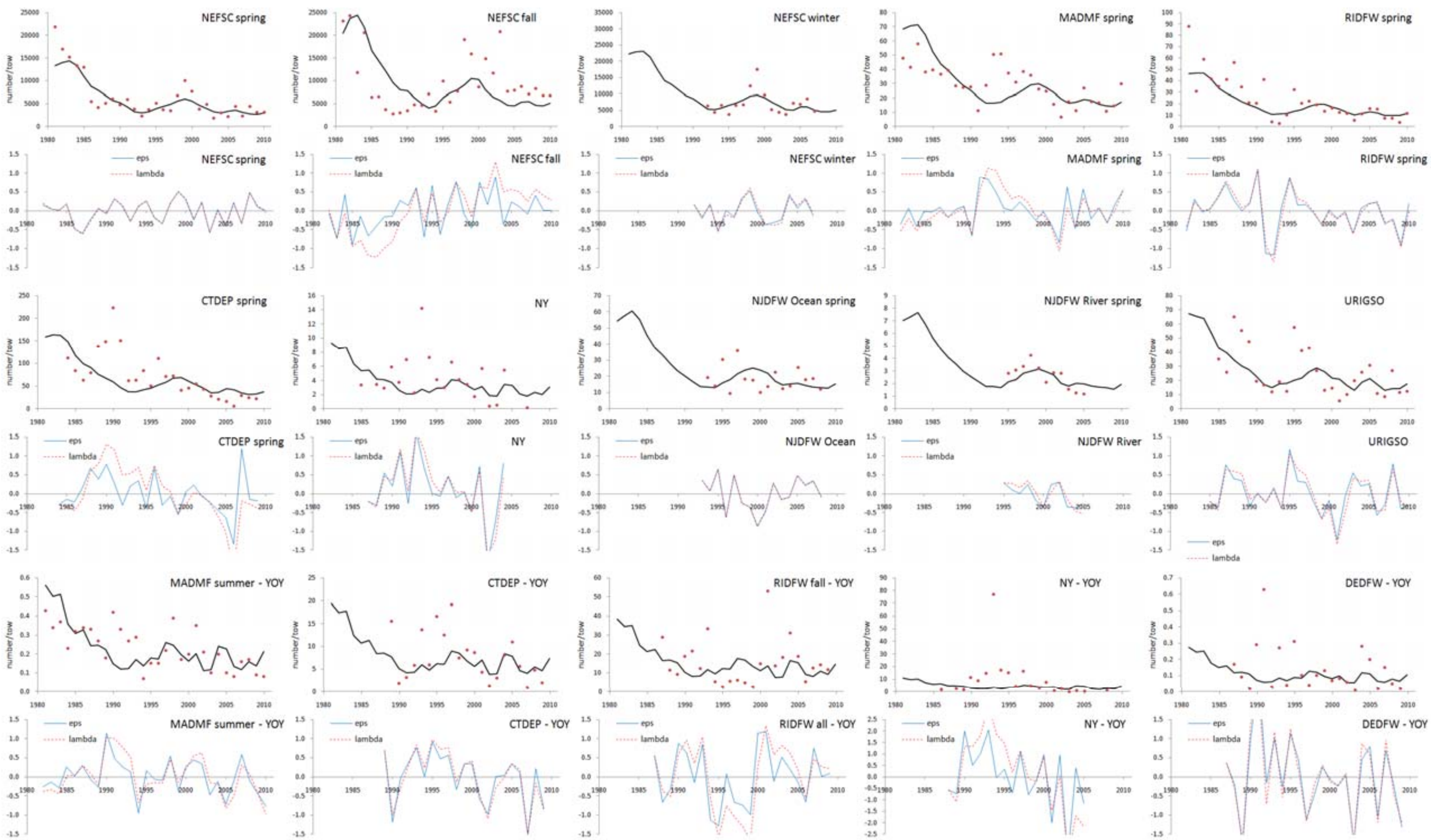

Fig. 5c: Fit of the New Base Case to the survey indices of abundance and corresponding survey standardised residuals. Residuals are shown both before ("lambda") and after ("eps") adjustment for serial correlation.

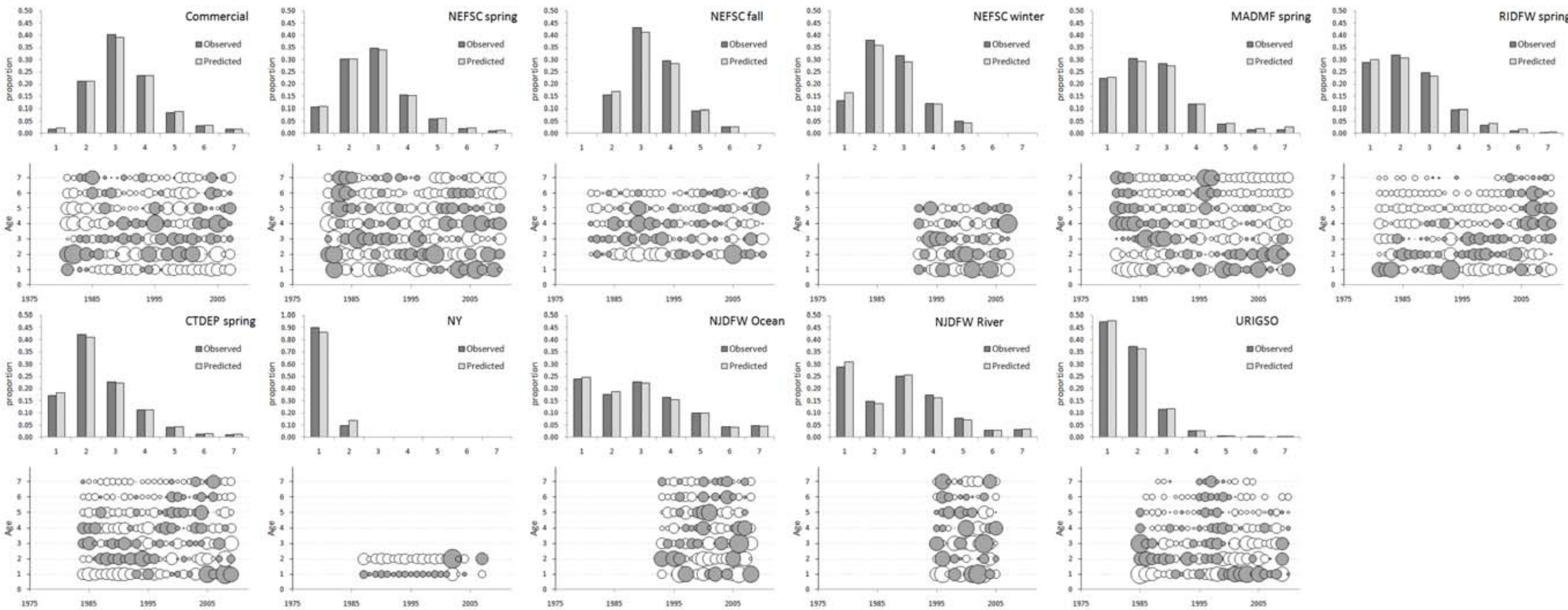

Fig. 6: Fit of the New Base Case to the commercial and survey catch-at-age data. The first and third rows compare the observed and predicted CAA as averaged over all years for which data are available, while the second and fourth rows plot the standardised residuals, with the size (area) of the bubbles being proportional to the magnitude of the corresponding standardised residuals. For positive residuals, the bubbles are grey, whereas for negative residuals, the bubbles are white.

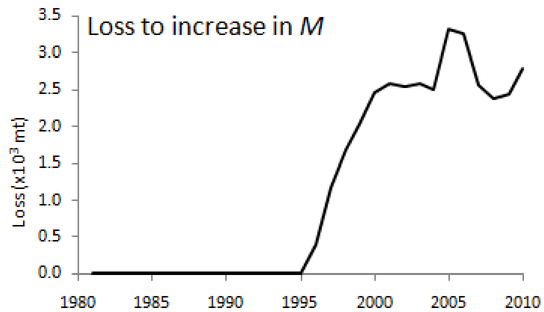

Fig. 7: Additional annual biomass loss from resource due to increase in *M* from 0.3 to 0.6 for the NBC.

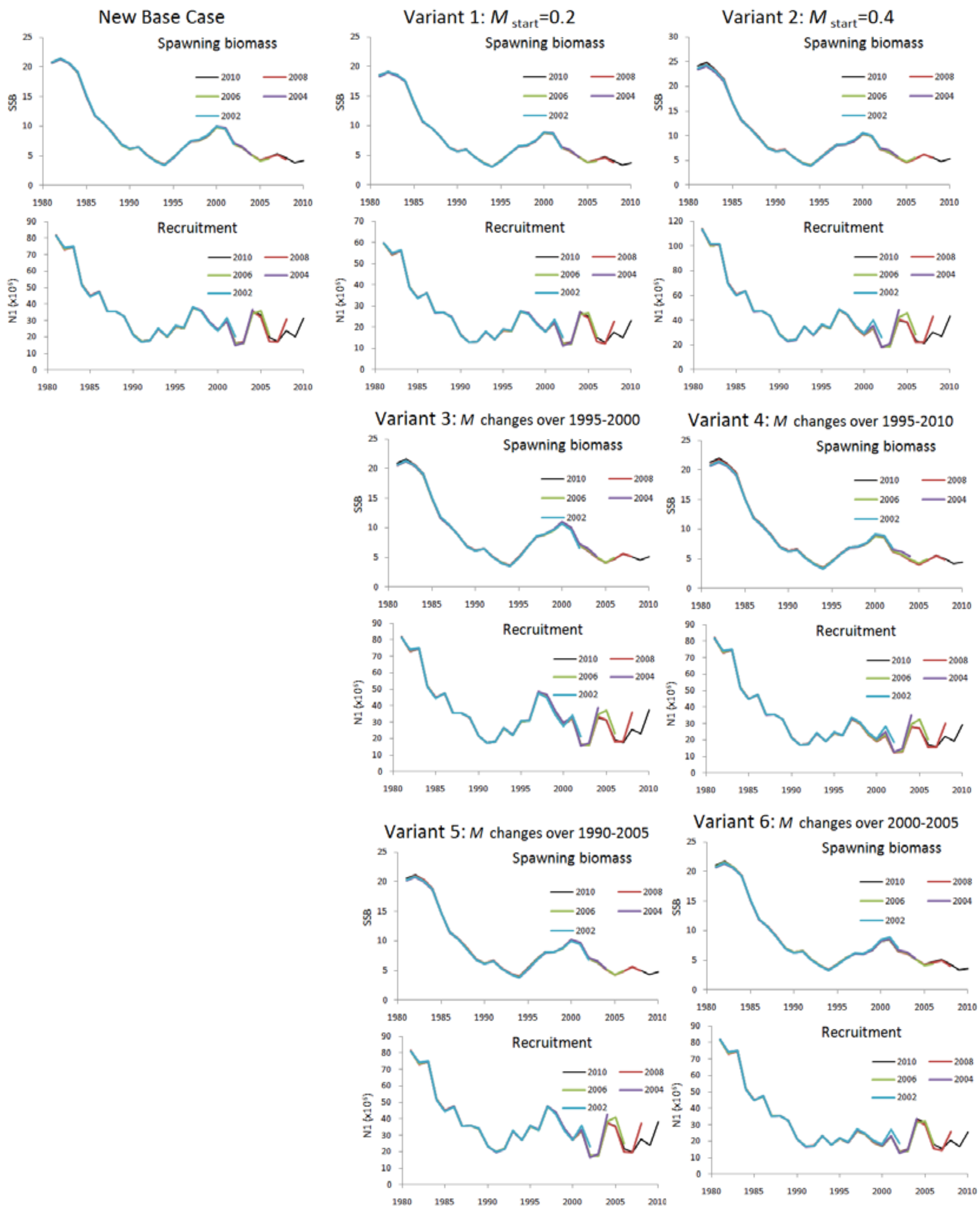

Fig. 8: Retrospective analysis of spawning biomass and recruitment for the New Base Case and some variants.

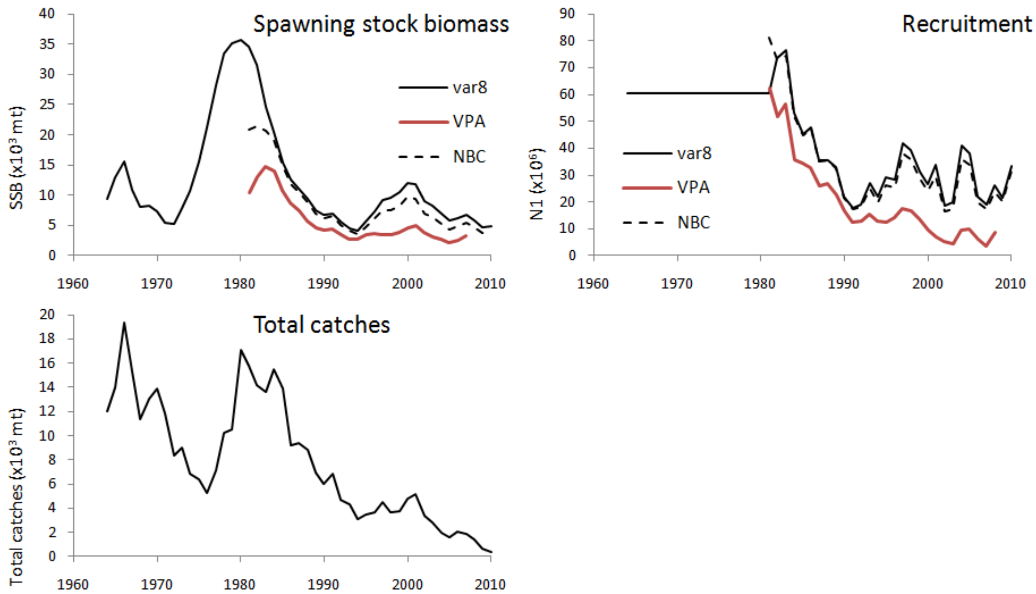

Fig. 9: Spawning stock biomass, recruitment and catch trajectories for the variant 8 of the New Base Case (starting in 1964), compared to the NBC and GARM3 SPLIT VPA run (Terceiro, 2008).

APPENDIX A – Data

Table A1: Total catch (metric tons) for SNE/MA winter flounder (M. Terceiro, pers. commn). Pre-1981, only the commercial landings are available; to compute the total catches, the average 1981-1985 ratio of commercial landings (0.62), commercial discards (0.09), recreational landings (0.28) and recreational discards (0.01) is assumed to apply over the pre-1981 period.

Year	Total catch (mt)	Year	Total catch (mt)	Year	Total catch (mt)
1964	*12053*	1980	*17138*	1996	3702
1965	*13995*	1981	15764	1997	4483
1966	*19315*	1982	14143	1998	3614
1967	*15285*	1983	13582	1999	3745
1968	*11402*	1984	15526	2000	4754
1969	*13074*	1985	13891	2001	5147
1970	*13874*	1986	9217	2002	3412
1971	*11881*	1987	9352	2003	2827
1972	*8370*	1988	8795	2004	1942
1973	*8988*	1989	6915	2005	1563
1974	*6869*	1990	5999	2006	2023
1975	*6422*	1991	6842	2007	1883
1976	*5266*	1992	4729	2008	1432
1977	*7117*	1993	4311	2009	639
1978	*10204*	1994	3092	2010	400
1979	*10552*	1995	3434		

Table A2. Catch at age matrix (000s) for SNE/MA winter flounder (M. Terceiro, pers. commn).

	1	2	3	4	5	6	7+
1981	1380	14183	14401	3608	666	182	111
1982	575	14153	12374	3713	608	212	202
1983	616	7232	13273	6111	1791	695	544
1984	493	11470	13940	4890	1770	873	803
1985	274	7342	12771	6013	2922	1819	1404
1986	216	6327	9101	4218	1053	442	357
1987	74	5265	8988	3084	2690	751	424
1988	85	3946	9401	3963	1206	978	303
1989	468	5275	7208	3541	861	226	214
1990	36	2110	6276	2933	768	196	142
1991	52	3029	7146	3349	860	252	113
1992	25	1507	4460	2582	673	162	53
1993	292	2200	3520	1897	714	188	138
1994	251	2612	2339	1280	337	97	39
1995	88	654	3112	2202	506	83	20
1996	171	1050	3289	2181	556	129	40
1997	88	1841	3488	2252	584	96	39
1998	16	1371	3043	1788	555	185	74
1999	5	2146	4062	1577	375	82	18
2000	43	1336	3436	2473	822	146	72
2001	35	1689	3503	2274	883	231	124
2002	14	478	1897	1830	925	324	115
2003	15	498	1802	1199	501	223	136
2004	36	378	999	858	331	223	167
2005	32	417	765	755	328	134	81
2006	39	758	1598	686	277	133	108
2007	7	334	1492	1033	299	85	32
2008	34	249	724	784	312	162	92
2009	83	195	271	268	211	66	30
2010	83	195	271	268	211	66	30

Table A3a. Total fishery mean weights-at-age (kg) for SNE/MA winter flounder (M. Terceiro, pers. commn).

	1	2	3	4	5	6	7+
1981	0.129	0.274	0.477	0.798	1.063	1.242	1.196
1982	0.092	0.263	0.440	0.697	1.052	1.257	1.840
1983	0.197	0.237	0.354	0.517	0.768	1.047	1.552
1984	0.148	0.261	0.370	0.546	0.695	0.915	1.284
1985	0.111	0.282	0.364	0.482	0.522	0.467	0.613
1986	0.129	0.292	0.398	0.480	0.685	0.879	0.961
1987	0.046	0.287	0.384	0.551	0.475	0.564	0.853
1988	0.039	0.279	0.351	0.508	0.634	0.517	0.827
1989	0.118	0.258	0.378	0.508	0.660	0.716	1.073
1990	0.082	0.295	0.394	0.525	0.672	0.808	0.990
1991	0.093	0.317	0.420	0.534	0.603	0.823	1.168
1992	0.079	0.287	0.427	0.599	0.802	0.945	1.395
1993	0.169	0.334	0.460	0.592	0.689	0.878	1.167
1994	0.162	0.311	0.429	0.550	0.750	0.985	1.281
1995	0.267	0.420	0.470	0.559	0.789	1.089	1.741
1996	0.136	0.380	0.464	0.607	0.824	0.851	1.085
1997	0.245	0.443	0.515	0.644	0.771	0.957	1.477
1998	0.196	0.362	0.465	0.568	0.665	1.090	1.116
1999	0.136	0.359	0.439	0.524	0.684	0.903	1.147
2000	0.106	0.407	0.492	0.622	0.729	0.975	1.079
2001	0.089	0.436	0.519	0.640	0.783	1.051	1.234
2002	0.135	0.372	0.499	0.617	0.747	0.927	1.143
2003	0.167	0.426	0.517	0.672	0.854	1.000	1.135
2004	0.094	0.384	0.549	0.619	0.786	0.945	1.251
2005	0.129	0.342	0.488	0.675	0.834	1.013	1.318
2006	0.118	0.379	0.468	0.652	0.872	1.065	1.289
2007	0.065	0.388	0.473	0.634	0.861	1.097	1.372
2008	0.110	0.355	0.477	0.597	0.754	0.939	1.238
2009	0.126	0.326	0.434	0.594	0.757	1.006	0.941
2010	0.126	0.326	0.434	0.594	0.757	1.006	0.941

Table A3b. Spawning stock biomass mean weights-at-age (kg) for SNE/MA winter flounder (M. Terceiro, pers. commn).

	1	2	3	4	5	6	7+
1981	0.102	0.234	0.420	0.728	1.005	1.179	1.196
1982	0.067	0.207	0.376	0.614	0.959	1.189	1.840
1983	0.179	0.173	0.321	0.490	0.744	1.049	1.552
1984	0.119	0.238	0.319	0.473	0.630	0.863	1.284
1985	0.080	0.228	0.326	0.441	0.530	0.533	0.613
1986	0.099	0.212	0.355	0.438	0.609	0.739	0.961
1987	0.025	0.220	0.351	0.494	0.477	0.602	0.853
1988	0.021	0.153	0.328	0.463	0.605	0.503	0.827
1989	0.087	0.137	0.342	0.449	0.605	0.688	1.073
1990	0.052	0.217	0.342	0.471	0.612	0.755	0.990
1991	0.064	0.202	0.373	0.483	0.576	0.769	1.168
1992	0.049	0.197	0.387	0.532	0.700	0.814	1.395
1993	0.138	0.207	0.393	0.531	0.658	0.852	1.167
1994	0.118	0.254	0.395	0.518	0.693	0.874	1.281
1995	0.237	0.306	0.410	0.512	0.700	0.962	1.741
1996	0.092	0.338	0.449	0.557	0.724	0.830	1.085
1997	0.215	0.299	0.465	0.577	0.712	0.910	1.477
1998	0.160	0.318	0.458	0.550	0.658	0.971	1.116
1999	0.094	0.293	0.412	0.504	0.643	0.815	1.147
2000	0.066	0.283	0.443	0.554	0.653	0.866	1.079
2001	0.055	0.272	0.479	0.586	0.725	0.930	1.234
2002	0.092	0.231	0.477	0.582	0.710	0.876	1.143
2003	0.127	0.290	0.463	0.609	0.766	0.907	1.135
2004	0.061	0.291	0.505	0.583	0.746	0.914	1.251
2005	0.090	0.222	0.451	0.630	0.755	0.931	1.318
2006	0.079	0.265	0.422	0.592	0.801	0.982	1.289
2007	0.037	0.261	0.439	0.573	0.785	1.016	1.372
2008	0.077	0.202	0.445	0.552	0.712	0.912	1.238
2009	0.096	0.227	0.406	0.552	0.699	0.914	0.941
2010	0.096	0.227	0.406	0.552	0.699	0.914	0.941

Table A3c. January-1 mean weights-at-age (kg) for SNE/MA winter flounder (M. Terceiro, pers. commn).

	1	2	3	4	5	6	7+
1981	0.090	0.216	0.395	0.695	0.978	1.149	1.196
1982	0.057	0.184	0.347	0.577	0.916	1.156	1.840
1983	0.171	0.148	0.305	0.477	0.732	1.050	1.552
1984	0.107	0.227	0.296	0.440	0.599	0.838	1.284
1985	0.068	0.204	0.308	0.422	0.534	0.570	0.613
1986	0.087	0.180	0.335	0.418	0.575	0.677	0.961
1987	0.019	0.192	0.335	0.468	0.478	0.622	0.853
1988	0.015	0.113	0.317	0.442	0.591	0.496	0.827
1989	0.075	0.100	0.325	0.422	0.579	0.674	1.073
1990	0.042	0.187	0.319	0.446	0.584	0.730	0.990
1991	0.053	0.161	0.352	0.459	0.563	0.744	1.168
1992	0.038	0.163	0.368	0.502	0.654	0.755	1.395
1993	0.125	0.162	0.363	0.503	0.642	0.839	1.167
1994	0.101	0.229	0.379	0.503	0.666	0.824	1.281
1995	0.224	0.261	0.382	0.490	0.659	0.904	1.741
1996	0.075	0.319	0.442	0.534	0.679	0.819	1.085
1997	0.202	0.246	0.442	0.547	0.684	0.888	1.477
1998	0.145	0.298	0.454	0.541	0.654	0.917	1.116
1999	0.079	0.265	0.399	0.494	0.623	0.775	1.147
2000	0.052	0.235	0.420	0.523	0.618	0.817	1.079
2001	0.044	0.215	0.460	0.561	0.698	0.875	1.234
2002	0.076	0.182	0.466	0.566	0.691	0.852	1.143
2003	0.110	0.240	0.439	0.579	0.726	0.864	1.135
2004	0.049	0.253	0.484	0.566	0.727	0.898	1.251
2005	0.075	0.179	0.433	0.609	0.719	0.892	1.318
2006	0.065	0.221	0.400	0.564	0.767	0.942	1.289
2007	0.028	0.214	0.423	0.545	0.749	0.978	1.372
2008	0.064	0.152	0.430	0.531	0.691	0.899	1.238
2009	0.084	0.189	0.393	0.532	0.672	0.871	0.941
2010	0.084	0.189	0.393	0.532	0.672	0.871	0.941

Table A4: Proportion mature-at-age for SNE/MA winter flounder (M. Terceiro, pers. commn).

1	2	3	4	5	6	7+
0.00	0.00	0.53	0.95	1.00	1.00	1.00

Table A5: Survey data in terms of total numbers for SNE/MA winter flounder (M. Terceiro, pers. commn).

	NEFSC spring	NEFSC fall	NEFSC winter	MADMF	RIDFW	CTDEP	NYDEC	NJDFW Ocean	NJDFW Rivers	URIGSO	YOY-MADMF	YOY-CTDEP	YOY-RIDFW	YOY-NYDEC	YOY-DEDFW
Month	4	10	3	5	5	5	5	5	5	5	1	1	1	1	1
Ages	1-7+	2-6+	1-5+	1-7+	1-7+	1-7+	1-2+	1-7+	1-7+	1-7+	1	1	1	1	1
1964	-	22029	-	-	-	-	-	-	-	-	-	-	-	-	-
1965	-	32829	-	-	-	-	-	-	-	-	-	-	-	-	-
1966	-	37305	-	-	-	-	-	-	-	-	-	-	-	-	-
1967	-	23655	-	-	-	-	-	-	-	-	-	-	-	-	-
1968	5919	21871	-	-	-	-	-	-	-	-	-	-	-	-	-
1969	13658	19446	-	-	-	-	-	-	-	-	-	-	-	-	-
1970	6609	16963	-	-	-	-	-	-	-	-	-	-	-	-	-
1971	4928	12387	-	-	-	-	-	-	-	-	-	-	-	-	-
1972	4516	9270	-	-	-	-	-	-	-	-	-	-	-	-	-
1973	15094	18457	-	-	-	-	-	-	-	-	-	-	-	-	-
1974	5907	6461	-	-	-	-	-	-	-	-	-	-	-	-	-
1975	1654	4879	-	-	-	-	-	-	-	-	-	-	-	-	-
1976	3698	5273	-	-	-	-	-	-	-	-	-	-	-	-	-
1977	5047	5705	-	-	-	-	-	-	-	-	-	-	-	-	-
1978	8028	11338	-	-	-	-	-	-	-	-	-	-	-	-	-
1979	3555	8987	-	-	-	-	-	-	-	-	-	-	-	-	-
1980	18284	24152	-	-	-	-	-	-	-	-	-	-	-	-	-
1981	21831	23138	-	47.80	87.98	-	-	-	-	-	0.43	-	-	-	-
1982	16918	24324	-	41.45	30.95	-	-	-	-	-	0.34	-	-	-	-
1983	15151	11859	-	58.13	58.95	-	-	-	-	-	0.37	-	-	-	-
1984	13360	20524	-	38.03	41.64	111.96	-	-	-	-	0.23	-	-	-	-
1985	12973	6462	-	39.50	34.98	83.57	3.35	-	-	35.04	0.32	-	-	-	-
1986	5446	6583	-	36.78	41.02	63.65	-	-	-	25.87	0.34	-	-	1.52	-
1987	4260	3703	-	39.16	56.22	79.93	3.43	-	-	65.05	0.33	-	29.00	-	0.17
1988	5155	2832	-	28.37	34.44	137.59	2.88	-	-	55.21	0.27	-	11.60	2.67	0.09
1989	6026	2977	-	27.40	20.88	148.19	5.89	-	-	47.41	0.18	15.50	9.19	1.47	0.02
1990	4816	3461	-	27.72	20.44	223.09	3.70	-	-	19.62	0.42	1.90	18.92	11.20	0.29
1991	5978	4792	-	11.02	40.97	150.21	6.94	-	-	16.80	0.33	3.10	21.48	8.73	0.63
1992	3824	4720	6303	28.96	4.41	61.38	2.24	-	-	11.89	0.27	5.80	12.19	14.72	0.03
1993	2323	7140	4421	50.41	2.92	63.59	14.24	19.17	-	19.06	0.29	13.70	33.33	76.87	0.27
1994	3679	3340	6580	50.83	10.26	84.45	7.28	14.06	-	12.44	0.07	6.00	5.29	17.10	0.04
1995	5083	9923	3834	37.37	32.19	50.12	4.11	30.41	2.82	57.63	0.15	16.60	2.52	14.93	0.31
1996	3679	5421	6511	30.92	20.68	110.61	2.99	9.40	3.05	41.20	0.15	12.50	5.64	4.10	0.10
1997	3485	7696	6752	38.51	22.27	71.31	6.56	36.02	3.35	43.15	0.22	19.20	6.22	16.25	0.04
1998	6728	19096	12382	35.87	19.22	72.90	4.09	18.20	4.25	26.97	0.39	7.47	4.70	4.42	0.10
1999	10093	15950	17563	25.99	13.46	41.35	3.47	17.79	3.23	13.24	0.17	9.28	2.56	3.11	0.13
2000	7672	8616	9619	24.63	16.32	45.42	1.71	10.10	2.11	14.64	0.20	8.70	14.97	7.52	0.07
2001	3800	14885	5267	15.80	12.49	54.51	5.69	13.83	2.84	5.43	0.35	4.30	53.00	0.90	0.08
2002	4937	11666	4352	6.69	11.56	43.72	0.36	22.58	2.80	9.96	0.21	1.30	13.73	2.31	0.06
2003	1864	20839	3747	17.72	5.56	27.84	0.54	12.52	1.57	19.71	0.10	3.06	18.12	0.07	0.01
2004	3001	7672	7253	11.14	11.16	20.46	5.49	14.21	1.27	25.81	0.20	8.10	31.22	0.86	0.28
2005	2251	7987	6925	27.00	15.74	16.10	-	25.67	1.17	30.75	0.10	10.96	18.72	0.50	0.20
2006	4381	8761	8479	17.62	15.36	5.58	-	18.13	-	10.82	0.08	5.63	5.28	-	0.02
2007	2275	7091	4784	16.69	7.33	28.66	0.15	18.58	-	8.54	0.16	0.93	12.72	-	0.15
2008	4381	8350	-	10.65	7.36	24.12	-	12.01	-	27.03	0.17	4.73	14.17	1.11	0.05
2009	3098	6753	-	14.56	3.67	22.59	-	-	-	11.54	0.09	1.97	11.65	-	0.02
2010	3098	6753	-	29.84	11.56	-	-	-	-	12.31	0.08	-	-	-	-

Table A6: Survey catch-at-age data mean numbers for SNE/MA winter flounder (M. Terceiro, pers. commn).

NEFSC spring

	1	2	3	4	5	6	7+
1981	2396	9681	8253	1138	315	24	24
1982	2808	7745	3776	1791	508	218	73
1983	1404	2348	5179	2977	1960	895	387
1984	581	3292	5228	2057	1113	702	387
1985	992	2929	5228	1743	1234	484	363
1986	242	1186	2759	750	363	121	24
1987	339	1307	1694	678	145	48	48
1988	218	1162	2396	895	387	48	48
1989	339	2299	2178	823	266	48	73
1990	557	1186	2154	678	121	97	24
1991	339	1452	2953	992	121	48	73
1992	339	944	1501	871	121	48	0
1993	339	847	629	290	169	24	24
1994	387	1815	1041	266	97	48	24
1995	532	1815	2106	532	73	0	24
1996	169	1307	1597	411	145	24	24
1997	315	1210	1355	436	145	24	0
1998	799	2929	1743	895	315	48	0
1999	992	4574	3267	871	266	97	24
2000	678	1694	2880	1573	653	169	24
2001	411	629	1138	1065	484	48	24
2002	266	1452	1355	920	557	266	121
2003	290	266	799	242	121	97	48
2004	726	460	702	629	266	121	97
2005	242	1089	266	387	169	73	24
2006	726	1501	1501	387	194	48	24
2007	266	339	871	629	97	24	48
2008	436	1476	1162	992	266	24	24
2009	557	920	799	508	242	48	24
2010	557	920	799	508	242	48	24

NEFSC fall

	2	3	4	5	6+
1981	4260	11182	6632	1041	24
1982	5155	12174	6026	726	242
1983	1839	5349	3243	1138	290
1984	3945	9245	4986	1501	847
1985	411	2517	2832	629	73
1986	387	2856	2396	726	218
1987	557	2178	871	73	24
1988	73	1549	871	290	48
1989	73	726	1549	532	97
1990	678	2009	629	121	24
1991	194	2154	2057	363	24
1992	169	2469	1767	290	24
1993	315	4211	1912	629	73
1994	1041	1259	847	194	0
1995	1089	5397	2614	726	97
1996	1404	2251	1525	218	24
1997	1476	3388	1936	750	145
1998	3582	8665	5325	1331	194
1999	3364	6849	4623	992	121
2000	1041	2299	3534	1307	436
2001	2178	5567	4889	1718	532
2002	1186	4332	3897	1525	726
2003	1259	9705	5688	2759	1428
2004	968	2565	2783	1113	242
2005	4574	1912	678	678	145
2006	1743	4429	1767	508	315
2007	1138	3364	1912	532	145
2008	1452	3969	2493	387	48
2009	1089	1767	1694	1501	702
2010	1089	1767	1694	1501	702

NEFSC winter

	1	2	3	4	5+
1992	1261	1485	1882	1261	414
1993	967	2003	933	311	207
1994	622	2003	3039	432	484
1995	69	1295	2176	294	0
1996	1744	1502	2677	553	35
1997	743	2573	2280	933	225
1998	725	6079	3368	1658	553
1999	1451	10258	3851	1658	345
2000	397	4870	3661	414	276
2001	1796	950	1209	933	380
2002	138	2314	1278	259	363
2003	155	984	1796	432	380
2004	3747	1761	743	622	380
2005	674	4421	622	743	466
2006	0	4145	2988	881	466
2007	35	967	1779	1779	225

MADMF

	1	2	3	4	5	6	7+
1981	8.65	9.07	13.66	9.72	3.81	1.20	1.69
1982	3.06	11.88	12.72	8.80	2.66	1.07	1.26
1983	1.71	15.32	17.85	14.11	4.14	2.34	2.66
1984	1.28	9.59	11.82	10.18	3.35	1.22	0.59
1985	3.13	9.98	16.48	6.35	2.48	0.75	0.33
1986	3.27	7.07	19.36	5.69	0.83	0.13	0.43
1987	9.44	7.74	12.35	6.59	2.21	0.22	0.61
1988	3.61	7.02	14.66	2.45	0.35	0.07	0.21
1989	2.26	6.08	12.30	4.68	1.01	0.29	0.78
1990	4.43	11.73	8.03	2.99	0.40	0.02	0.12
1991	1.65	2.88	4.90	1.18	0.24	0.13	0.04
1992	8.06	7.40	6.73	4.21	1.67	0.60	0.29
1993	16.03	18.75	12.02	2.76	0.65	0.14	0.06
1994	12.15	17.35	14.96	4.72	0.62	0.59	0.44
1995	14.31	11.14	8.10	1.93	0.61	0.80	0.48
1996	4.98	10.12	7.72	2.86	2.00	1.46	1.78
1997	10.43	9.30	10.27	4.26	1.32	1.00	1.93
1998	8.62	13.09	7.21	3.51	1.47	1.22	0.75
1999	9.66	8.00	5.81	1.89	0.21	0.25	0.17
2000	6.41	7.78	6.68	1.74	1.09	0.46	0.47
2001	5.47	4.73	2.39	2.02	0.66	0.20	0.33
2002	0.94	3.00	1.55	0.82	0.29	0.08	0.01
2003	4.12	3.78	6.15	2.25	1.14	0.24	0.04
2004	3.46	3.15	1.97	1.67	0.56	0.21	0.12
2005	14.05	8.42	2.68	1.07	0.59	0.11	0.08
2006	3.19	9.61	2.98	1.12	0.32	0.20	0.20
2007	3.69	5.59	5.32	1.63	0.35	0.09	0.02
2008	3.15	5.14	1.73	0.42	0.13	0.02	0.06
2009	2.60	6.03	4.09	1.06	0.68	0.06	0.04
2010	14.20	6.94	5.57	1.74	0.93	0.40	0.06

Table A6: continued

RIDFW

	1	2	3	4	5	6	7+
1981	45.67	27.88	12.86	1.27	0.23	0.05	0.02
1982	13.42	9.74	5.02	2.31	0.33	0.11	0.02
1983	29.49	9.79	10.98	6.00	2.13	0.56	0.00
1984	6.67	16.79	13.94	2.96	0.83	0.35	0.10
1985	6.01	15.69	10.35	2.24	0.60	0.08	0.01
1986	11.94	15.63	9.59	2.63	1.14	0.09	0.00
1987	15.30	24.59	13.14	2.66	0.41	0.08	0.04
1988	8.93	12.37	9.53	2.92	0.68	0.01	0.00
1989	4.79	8.20	4.95	2.33	0.51	0.07	0.03
1990	6.46	6.36	4.88	2.16	0.48	0.04	0.06
1991	11.21	14.36	12.00	2.78	0.41	0.10	0.11
1992	1.30	0.95	1.17	0.75	0.20	0.04	0.00
1993	2.32	0.35	0.17	0.06	0.02	0.00	0.00
1994	2.84	4.56	1.97	0.63	0.19	0.04	0.03
1995	9.36	11.36	9.87	1.47	0.13	0.00	0.00
1996	3.11	8.36	7.47	1.56	0.15	0.03	0.00
1997	4.90	8.77	6.86	1.48	0.26	0.00	0.00
1998	2.11	9.47	5.90	1.60	0.13	0.01	0.00
1999	1.71	6.52	4.26	0.82	0.09	0.06	0.00
2000	2.88	4.98	5.51	2.19	0.66	0.10	0.00
2001	2.46	3.47	3.67	2.23	0.63	0.02	0.01
2002	1.60	4.76	3.21	1.24	0.54	0.15	0.06
2003	1.72	0.86	1.76	0.50	0.30	0.28	0.14
2004	5.47	3.97	1.03	0.44	0.12	0.09	0.04
2005	8.86	2.41	1.73	1.38	0.79	0.43	0.14
2006	2.07	4.72	5.24	2.24	0.74	0.30	0.05
2007	1.19	1.12	2.03	1.62	0.86	0.43	0.08
2008	3.29	1.00	1.00	1.12	0.67	0.22	0.06
2009	0.37	1.17	0.80	0.70	0.47	0.12	0.04
2010	3.24	2.68	3.13	1.24	1.06	0.18	0.03

CTDEP

	1	2	3	4	5	6	7+
1984	8.21	44.01	31.83	20.96	4.23	1.23	1.49
1985	4.11	28.46	32.88	14.17	2.33	0.82	0.8
1986	6.69	26	15.53	12.26	2.05	0.5	0.62
1987	7.32	44.69	14.56	5.05	6.55	1.28	0.48
1988	14.49	71.87	39.1	8.59	1.83	1.46	0.25
1989	13.56	78.43	41.23	10.85	2.84	0.98	0.3
1990	11.31	131.52	64.97	8.97	4.09	1.96	0.27
1991	8.52	66.99	60.39	9.31	4.05	0.8	0.15
1992	6.8	31.32	12.78	8.97	1.1	0.36	0.05
1993	19.11	19.87	15.46	4.81	3.24	0.8	0.3
1994	9.57	64.14	5.86	3.01	1.14	0.49	0.24
1995	14.35	23.69	9.77	1.36	0.63	0.2	0.12
1996	11.46	59.07	24.17	14.41	0.97	0.28	0.25
1997	12.53	25.53	19.41	9.45	3.76	0.51	0.12
1998	11.22	32.4	12.23	12.67	3.15	0.99	0.24
1999	6.56	12.42	11.27	6.09	3.2	1.14	0.67
2000	7.11	16.66	8.4	7.7	3.42	1.53	0.6
2001	8.45	19.6	10.85	8.06	5.46	1.28	0.81
2002	6.27	19.9	9.56	4.43	1.95	1.02	0.59
2003	2.47	7.83	8.71	4.79	1.95	0.77	1.32
2004	6.34	3.84	3.49	3.88	1.91	0.64	0.36
2005	7.06	6.18	0.84	0.81	0.67	0.21	0.33
2006	1.14	2.6	1.1	0.19	0.14	0.17	0.24
2007	2.98	10.83	10.7	3.1	0.61	0.15	0.29
2008	11.48	3.48	4.19	4.12	0.65	0.12	0.08
2009	7.56	11.21	1.02	1.31	1.21	0.22	0.06

NYDEC

	1	2+
1985	3.05	0.3
1986	-	-
1987	3.31	0.12
1988	2.57	0.31
1989	5.54	0.35
1990	3.44	0.26
1991	6.35	0.59
1992	2.04	0.2
1993	14.12	0.12
1994	6.96	0.32
1995	3.84	0.27
1996	2.84	0.15
1997	6.45	0.11
1998	3.8	0.29
1999	3.25	0.22
2000	1.56	0.15
2001	5.52	0.17
2002	0.17	0.19
2003	0.45	0.09
2004	5.38	0.11
2005	-	-
2006	-	-
2007	0.11	0.04

NJDFW Ocean

	1	2	3	4	5	6	7+
1993	5.1	6.5	2.5	2.4	1.7	0.4	0.57
1994	3.7	4.2	3.9	1.4	0.4	0.3	0.16
1995	8	10.1	8.6	2.4	0.9	0.3	0.11
1996	0.6	2.9	2.6	1.9	0.9	0.3	0.2
1997	16.6	5.4	6.1	6	1.5	0.3	0.12
1998	4.5	3.9	4.8	3.3	1.2	0.4	0.1
1999	2.4	2.2	5.9	3.1	2.9	0.7	0.59
2000	0.7	0.3	2.1	3.3	2	0.9	0.8
2001	3.9	0.6	1.3	2.7	3.8	0.7	0.83
2002	5.81	3.21	4.55	2.22	2.8	2.16	1.83
2003	2.08	1.1	4.79	1.24	1.09	0.87	1.35
2004	6.48	0.72	1.42	2.08	0.56	1.38	1.57
2005	4.97	10.04	2.55	2.76	2.61	1.32	1.42
2006	0.64	2.49	9.43	3.23	0.62	0.75	0.97
2007	3.8	0.67	4.33	6.09	1.51	0.62	1.56
2008	5.57	1.59	0.83	1.75	1.69	0.21	0.37

NJDFW Rivers

	1	2	3	4	5	6	7+
1995	0.6	0.3	1.4	0.4	0.1	0.01	0.01
1996	0.3	0.9	0.7	0.7	0.2	0.1	0.15
1997	1.1	0.4	0.9	0.4	0.4	0.1	0.05
1998	1.9	0.9	0.4	0.7	0.2	0.1	0.05
1999	0.2	0.5	1.4	0.5	0.4	0.1	0.13
2000	0.4	0.2	0.4	0.8	0.2	0.1	0.01
2001	1.4	0.3	0.2	0.4	0.4	0.1	0.04
2002	1.21	0.48	0.49	0.18	0.27	0.13	0.04
2003	0.05	0.22	0.9	0.18	0.03	0.1	0.09
2004	0.67	0.02	0.1	0.29	0.05	0	0.14
2005	0.42	0.24	0.17	0.2	0.09	0.02	0.03

URIGSO

	1	2	3	4	5	6	7+
1985	2.09	18.31	12.15	1.94	0.56	0	0
1986	6.87	13.85	4.23	0.83	0.08	0.02	0
1987	16.69	35.86	10.75	1.54	0.2	0.02	0
1988	22.35	24	7.82	0.95	0.04	0	0.06
1989	19.74	24.18	2.4	0.93	0.12	0.03	0.01
1990	6.22	10.33	2.18	0.75	0.1	0	0.04
1991	7.81	5.84	2.55	0.47	0.07	0.05	0
1992	5.81	4.17	1.35	0.47	0.08	0.01	0
1993	9.03	8.76	0.9	0.3	0.06	0.02	0
1994	4.52	6.22	1.5	0.17	0.02	0.01	0
1995	34.71	13.64	7.26	1.38	0.21	0.26	0.17
1996	14.22	19.68	5.41	1.11	0.43	0.25	0.11
1997	18.06	15.55	6.97	1.56	0.41	0.24	0.36
1998	7.5	13.73	3.9	1.25	0.31	0.21	0.07
1999	7.08	3.07	2.07	0.72	0.09	0.15	0.06
2000	7.47	3.77	2.28	0.82	0.11	0.14	0.05
2001	4.1	0.9	0.27	0.11	0.02	0.03	0.01
2002	5.39	3.18	0.99	0.34	0.06	0.01	0
2003	14.16	4.3	0.82	0.26	0.12	0.03	0.01
2004	18.36	6.47	0.5	0.32	0.09	0.04	0.02
2005	23.59	6.31	0.66	0.16	0.03	0	0
2006	5.2	4.04	1.22	0.34	0.03	0.01	0
2007	4.41	2.88	0.95	0.24	0.06	0	0
2008	18.74	7.41	0.72	0.15	0.01	0	0
2009	3.65	5.92	1.65	0.21	0.11	0.01	0
2010	7.73	3.16	1.1	0.25	0.05	0.02	0

Appendix B - The Age-Structured Production Model

The model used for these assessments is an Age-Structured Production Model (ASPM) (e.g. Hilborn, 1990). Models of this type fall within the more general class of Statistical Catch-at-Age Analyses. The approach used in an ASPM assessment involves constructing an age-structured model of the population dynamics and fitting it to the available abundance indices by maximising the likelihood function. The model equations and the general specifications of the model are described below, followed by details of the contributions to the (penalised) log-likelihood function from the different sources of data available and assumptions concerning the stock-recruitment relationship. Quasi-Newton minimization is used to minimize the total negative log-likelihood function (the package AD Model Builder™, Otter Research, Ltd is used for this purpose).

B.1. Population dynamics

B.1.1 Numbers-at-age

The resource dynamics are modelled by the following set of population dynamics equations:

$$N_{y+1,1} = R_{y+1} \qquad \text{(B1)}$$

$$N_{y+1,a+1} = \left(N_{y,a}\, e^{-M_{y,a}/2} - C_{y,a}\right) e^{-M_{y,a}/2} \qquad \text{for } 1 \le a \le m-2 \qquad \text{(B2)}$$

$$N_{y+1,m} = \left(N_{y,m-1}\, e^{-M_{y,m-1}/2} - C_{y,m-1}\right) e^{-M_{y,m-1}/2} + \left(N_{y,m}\, e^{-M_{y,m}/2} - C_{y,m}\right) e^{-M_{y,m}/2} \qquad \text{(B3)}$$

where

$N_{y,a}$ is the number of fish of age *a* at the start of year *y* (which refers to a calendar year),

R_y is the recruitment (number of 1-year-old fish) at the start of year *y*,

$M_{y,a}$ denotes the natural mortality rate for fish of age *a* in year *y*,

$C_{y,a}$ is the predicted number of fish of age *a* caught in year *y*, and

m is the maximum age considered (taken to be a plus-group).

B.1.2. Recruitment

In line with the approach used at GARM in 2008 (Terciero, 2008), the number of recruits at the start of year *y* is assumed to have two constant levels, depending on the spawning biomass level which corresponds in this case to two particular periods, and allowing for annual fluctuation about the deterministic relationship:

$$R_y = \begin{cases} A^1 e^{(\varsigma_y - (\sigma_R^1)^2/2)} & \text{for } 1981 \le y \le 1988 \\ A^2 e^{(\varsigma_y - (\sigma_R^2)^2/2)} & \text{for } y \ge 1989 \end{cases} \qquad \text{(B4)}$$

where

ς_y reflects fluctuation about the expected recruitment for year *y*, which is assumed to be normally distributed with standard deviation $\sigma_R^1 = 0.5$ for the period 1981-1988 and $\sigma_R^2 = 0.3$ for the period 1989-2010; these residuals are treated as estimable parameters in the model fitting process. The value for the earlier period was chosen to be rather uninformative. For the second period, it is rounded to a value slightly above the standard deviations of recruitment residuals shown in a number of these assessments. This value choice is intended to be somewhat informative for the most recent recruitment estimates for which the corresponding cohorts have been sampled relatively few times so that their initial magnitudes are not well estimated by the catch-at-age data alone,

A^1 and A^2 are constants, and

B_y^{sp} is the spawning biomass, computed as:

$$B_y^{sp} = \sum_{a=1}^{m} f_{y,a} w_{y,a}^{strt} N_{y,a} e^{-M_{y,a}\delta} \quad \text{(B5)}$$

where

$w_{y,a}^{sp}$ is the mass of fish of age *a* during spawning, and

$f_{y,a}$ is the proportion of fish of age *a* that are mature,

δ is the proportion of the natural mortality that occurs before spawning (0.2 here).

B.1.3. Total catch and catches-at-age

The catch by mass in year *y* is given by:

$$C_y = \sum_{a=1}^{m} w_{y,a}^{mid}\, C_{y,a} = \sum_{a=1}^{m} w_{y,a}^{mid}\, N_{y,a}\, e^{-M_{y,a}/2}\, S_{y,a}\, F_y \quad \text{(B6)}$$

where

$w_{y,a}^{mid}$ denotes the mass of fish of age *a* landed in year *y*,

$C_{y,a}$ is the catch-at-age, i.e. the number of fish of age *a*, caught in year *y*,

$S_{y,a}$ is the commercial selectivity (i.e. combination of availability and vulnerability to fishing gear) at age *a* for year *y*; when $S_{y,a}$ = 1, the age-class *a* is said to be fully selected, and

F_y is the proportion of a fully selected age class that is fished.

The model estimate of the mid-year exploitable ("available") component of biomass is calculated by converting the numbers-at-age into mid-year mass-at-age (using the individual weights of the landed fish) and applying natural and fishing mortality for half the year:

$$B_y^{ex} = \sum_{a=1}^{m} w_{y,a}^{mid} S_{y,a} N_{y,a} e^{-M_{y,a}/2} (1 - S_{y,a} F_y \ / 2) \tag{B7}$$

For survey estimates (in numbers):

$$N_y^{surv,i} = \sum_{a=1}^{m} S_a^i N_{y,a} e^{-M_{y,a} \frac{\varpi^1}{12}} \left(1 - S_{y,a} F_y \ \frac{\varpi^1}{12}\right) \tag{B8}$$

where

S_a^i is the survey selectivity for age *a* and survey *i*,

ϖ^i is the month in which survey *i* has taken place.

B.1.4. Initial conditions

For the first year (y_0) considered in the model therefore, the stock is assumed to be at a level $B_{y_0}^{sp}$ (estimated in the model fitting procedure), with the starting age structure:

$$N_{y_0,a} = R_{start} N_{start,a} \qquad \text{for } 1 \le a \le m \tag{B9}$$

where

$$N_{start,1} = 1 \tag{B10}$$

$$N_{start,a} = N_{start,a-1} e^{-M_{y_0,a-1}} (1 - \phi S_{y_0,a-1}) \qquad \text{for } 2 \le a \le m-1 \tag{B11}$$

$$N_{start,m} = N_{start,m-1} e^{-M_{y_0,m-1}} (1 - \phi S_{y_0,m-1}) \Big/ (1 - e^{-M_{y_0,m}} (1 - \phi S_{y_0,m})) \tag{B12}$$

where ϕ characterises the average fishing proportion over the years immediately preceding y_0.

B.2. The (penalised) likelihood function

The model is fit to survey abundance indices, and commercial and survey catch-at-age data to estimate model parameters (which may include residuals about the stock-recruitment function, the fishing selectivities, the annual catches or natural mortality, facilitated through the incorporation of the penalty functions described below). Contributions by each of these to the negative of the (penalised) log-likelihood (- ℓnL) are as follows.

B.2.1. Survey abundance data

The likelihood is calculated assuming that an observed survey index is log-normally distributed about its expected value:

$$I_y^i = \hat{I}_y^i \exp\left(\varepsilon_y^i\right) \quad \text{or} \quad \varepsilon_y^i = \ell n\left(I_y^i\right) - \ell n\left(\hat{I}_y^i\right) \tag{B13}$$

where

I_y^i is the survey index for year *y* and series *i*,

$\hat{I}_y^i = \hat{q}^i N_y^{surv,i}$ is the corresponding model estimate, where $N_y^{surv,i}$ is the model estimate, given by equation (B8),

$\hat{q}^i$ is the constant of proportionality (catchability) for index *i*, and

ε_y^i from $N\left(0,\left(\sigma_y^i\right)^2\right)$.

For these analyses, selectivities are estimated as detailed in section B.3.1 below.

The contribution of the survey abundance data to the negative of the log-likelihood function (after removal of constants) is then given by:

$$-\ell\mathrm{n}\, L^{survey} = \sum_i \sum_y \left[\ell\mathrm{n}\left(\sigma_y^i\right) + \left(\varepsilon_y^i\right)^2 / 2\left(\sigma_y^i\right)^2\right] \qquad \text{(B14)}$$

where

σ_y^i is the standard deviation of the residuals for the logarithm of index *i* in year *y*.

Homoscedasticity of residuals is assumed, so that $\sigma_y^i = \sigma^i$ is estimated in the fitting procedure by its maximum likelihood value:

$$\hat{\sigma}^i = \sqrt{1/n_i \sum_y \left(\ell\mathrm{n}(I_y^i) - \ell\mathrm{n}(q^i N_y^{surv,i})\right)^2} \qquad \text{(B15)}$$

where

n_i is the number of data points for survey index *i*.

The catchability coefficient q^i for survey index *i* is estimated by its maximum likelihood value:

$$\ell n\, \hat{q}^i = 1/n_i \sum_y \left(\ln I_y^i - \ln N_y^{surv,i}\right) \qquad \text{(B16)}$$

To allow for first order serial correlation between the survey residuals, a serial correlation coefficient ρ^i would be estimated for each survey index:

$$\varepsilon_y^i = \lambda_y^i - \rho\lambda_{y-1}^i \qquad \text{(B17)}$$

where

$\lambda_y^i = \ell\mathrm{n}\left(I_y^i\right) - \ell\mathrm{n}\left(\hat{I}_y^i\right)$

and the summation in equation (B.16) extends over one less year.

B.2.2. Commercial catches-at-age

The contribution of the catch-at-age data to the negative of the log-likelihood function under the assumption of an "adjusted" lognormal error distribution is given by:

$$-\ell\text{n}L^{CAA}=\sum_y\sum_a\left[\ell n\left(\sigma_{com}/\sqrt{p_{y,a}}\right)+p_{y,a}\left(\ell n\,p_{y,a}-\ell n\,\hat{p}_{y,a}\right)^2/2\left(\sigma_{com}\right)^2\right] \qquad \text{(B18)}$$

where

$p_{y,a}=C_{y,a}/\sum_{a'}C_{y,a'}$ is the observed proportion of fish caught in year *y* that are of age *a*,

$\hat{p}_{y,a}=\hat{C}_{y,a}/\sum_{a'}\hat{C}_{y,a'}$ is the model-predicted proportion of fish caught in year *y* that are of age *a*, where

$$\hat{C}_{y,a}=N_{y,a}\,e^{-M_{y,a}/2}\,S_{y,a}\,F_y \qquad \text{(B19)}$$

and

σ_{com} is the standard deviation associated with the catch-at-age data, which is estimated in the fitting procedure by:

$$\hat{\sigma}_{com}=\sqrt{\sum_y\sum_a p_{y,a}\left(\ell n\,p_{y,a}-\ell n\,\hat{p}_{y,a}\right)^2/\sum_y\sum_a 1} \qquad \text{(B20)}$$

B.2.3. Survey catches-at-age

The survey catches-at-age are incorporated into the negative of the log-likelihood in an analogous manner to the commercial catches-at-age, assuming an adjusted log-normal error distribution (equation (B18)) where:

$p_{y,a}=C^{surv}_{y,a}/\sum_{a'}C^{surv}_{y,a'}$ is the observed proportion of fish of age *a* in year *y*, with

$$C^{surv,i}_{y,a}=S^i_a N_{y,a}e^{-M_{y,a}\frac{\varpi^1}{12}}\left(1-S_{y,a}F_y\,\frac{\varpi^1}{12}\right) \qquad \text{(B21)}$$

$\hat{p}_{y,a}$ is the expected proportion of fish of age *a* in year *y* in the survey.

B.2.4. Stock-recruitment function residuals

The stock-recruitment residuals are assumed to be log-normally distributed. Thus, the contribution of the recruitment residuals to the negative of the (now penalised) log-likelihood function is given by:

$$-\ell nL^{SRpen}=\sum_{y=y1}^{1988}\left[\varepsilon_y^2\Big/2\left(\sigma_R^1\right)^2\right]+\sum_{1989}^{y2}\left[\varepsilon_y^2\Big/2\left(\sigma_R^2\right)^2\right] \qquad \text{(B22)}$$

where

ε_y from $N\left(0,\left(\sigma_R^1\right)^2\right)$ for year *y*1 to 1988, and from $N\left(0,\left(\sigma_R^2\right)^2\right)$ for year 1989 to *y2*.

B.3. Model parameters

B.3.1. Fishing selectivity-at-age:

The commercial and survey fishing selectivities are estimated separately for ages 1-7+. The convention used is to set S_a to 1 for the age with the highest selectivity.

B.3.2.: Other parameters reported in Tables 1-3 and elsewhere

Mohn's ρ

Retrospective evaluations involved four model runs with successively earlier terminal years (2008, 2006, 2004 and 2002), in addition to the run with the full data set (2010). Mohn's ρ for a statistic *S* is calculated as:

$$\rho_S = \sum_{i=1}^{4} \frac{\left(s_{2010-2i} - S_{2010-2i}\right)}{S_{2010-2i}} \Big/ 4 \qquad \text{(B23)}$$

Where S_j is the estimated statistic (here spawning biomass or recruitment) for year *j* from the run with the full data set and s_j is the estimated statistic for year *j* from the model with *j* as the terminal year.

Loss to increased *M*

For each year of the assessment period, a "pseudo" numbers-at-age matrix (N^*) is computed, assuming M=M^1, the natural mortality at the start of the assessment period:

$$N^*_{y+1,a+1} = \left(N_{y,a}\, e^{-M^1/2} - C_{y,a}\right) e^{-M^1/2} \qquad \text{for } 1 \le a \le m-2 \qquad \text{(B24)}$$

$$N^*_{y+1,m} = \left(N_{y,m-1}\, e^{-M^1/2} - C_{y,m-1}\right) e^{-M^1/2} + \left(N_{y,m}\, e^{-M^1/2} - C_{y,m}\right) e^{-M^1/2} \qquad \text{(B25)}$$

The loss to increased *M* is then calculated as:

$$L = \sum_{y=1981}^{2010} \sum_{a=1}^{mm} \left(L^1_{y,a} - L^2_{y,a}\right) \qquad \text{(B26)}$$

where

$$L^1_{y,a} = w^{mid}_{y,a}\left(N_{y,a} - N_{y+1,a+1} + C_{y,a}\right) \qquad \text{(B27)}$$

$$L^2_{y,a} = w^{mid}_{y,a}\left(N_{y,a} - N^*_{y+1,a+1} + C_{y,a}\right) \qquad \text{(B28)}$$

σ_R_out

$$\sigma_R\_\text{out} = \sum_{y=y1}^{y2} \left(\varsigma_y\right)^2 \Big/ \sum_{y=y1}^{y2} 1 \qquad \text{(B29)}$$

This is calculated for two periods: a) *y*1=1981, *y*2=1988 and b) *y*1=1989, *y*2=2010

Calculation of MSY

The equilibrium catch for a fully selected fishing proportion *F* is calculated as:

$$C(F)=\sum_{a} w_a^{mid} S_a F N_a(F) e^{-(M_a/2)} \tag{B30}$$

where $w_a^{mid} = \sum_{y1=2006}^{2010} w_{y,a}^{mid} \Big/ 5$, $S_a = S_{2010,a}$ and $M_a = M_{2010,a}$

and where numbers-at-age *a* are given by:

$$N_a(F)=\begin{cases} R_1(F) & \text{for } a=1 \\ N_{a-1}(F)e^{-M_{a-1}}(1-S_{a-1}F) & \text{for } 1<a<m \\ \dfrac{N_{m-1}(F)e^{-M_{m-1}}(1-S_{m-1}F)}{\left(1-e^{-M_m}(1-S_m F)\right)} & \text{for } a=m \end{cases} \tag{B31}$$

where

$$R_1(F)=A^1 \text{ or } A^2 \tag{B32}$$

The maximum of $C(F)$ is then found by searching over *F* to give F_{MSY}, with the associated spawning biomass and yield given by

$$B_{\text{MSY}}^{sp} = \sum_{a} f_a w_a^{strt} N_a(F_{\text{MSY}}) e^{-M_a\delta} \tag{B33}$$

$$MSY = \sum_{a} w_a^{mid} S_a F_{\text{MSY}} N_a(F_{\text{MSY}}) e^{-(M_a/2)} \tag{B34}$$

where $w_a^{strt} = \sum_{y1=2006}^{2010} w_{y,a}^{strt} \Big/ 5$ and $f_a = \sum_{y1=2006}^{2010} f_{y,a} \Big/ 5$

ADDITIONAL REFERENCE

Hilborn, R. 1990. Estimating the parameters of full age-structured models from catch and abundance data. International North Pacific Fisheries Commission Bulletin, 50: 207-213.

Update of the Southern New England/Mid-Atlantic Winter Flounder Resource New Base Case SCAA using updated data

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Introduction

This paper presents an update of the SCAA "New Base Case" for the Southern New England/Mid-Atlantic winter flounder resource of Rademeyer and Butterworth (2011) using the most recent data available (Terceiro, 2011).

Data and Methodology

The data tables, which have been updated from those used in Rademeyer and Butterworth (2011), are given in Appendix A with the updated data shown in bold. Although the units of NEFSC surveys have changed (given here as stratified mean number per tow instead of mean total number), only the 2010 values are new (i.e. changed).

The methodology is as described in Appendix B of Rademeyer and Butterworth (2011), with the New Base Case specifications.

Results and Discussion

The results for the "New Base Case" and "New Base Case with updated data" are compared in Table 1. Retrospective patterns for spawning biomass and recruitment trajectories are shown in Fig. 1 for the "New Base Case with updated data" and the estimated spawning biomass and recruitment trends are shown in Fig. 2. These show very little change in moving from the original to the new data.

References

Rademeyer R.A. and Butterworth D.S. 2011. Initial applications of statistical catch-at-age methodology to the Southern New England/Mid-Atlantic winter flounder resource. Document to this workshop.

Terceiro M. 2008. J. Southern New England/Mid-Atlantic winter flounder. Appendix to the Report of the 3rd Groundfish Assessment Review Meeting (GARM III): Assessment of 19 Northeast Groundfish Stocks through 2007, Northeast Fisheries Science Center, Woods Hole, Massachusetts, August 4-8, 2008 http://www.nefsc.noaa.gov/publications/crd/crd0816/pdfs/garm3j.pdf

Table 1: Results for the New Base Case as in Rademeyer and Butterworth (2011) and now with the updated data. Biomass units are '000t. The two recruitment values refer to the two recruitment periods, i.e. 1989-2010 and 1981-1988 respectively. MSY and related quantities have been computed for each of these recruitment levels, assuming the natural mortality in recent years.

	New Base Case				New Base Case - Updated data			
'-lnL:overall	-864.1				-848.9			
'-lnL:Survey	-49.8				-42.3			
'-lnL:CAA	-91.7				-95.8			
'-lnL:CAAsurv	-701.7				-690.3			
'-lnL:RecRes	-21.9				-21.7			
'-lnL:SelSmoothing	0.9				1.3			
Mohn's rho: SSB	-0.03				-0.03			
Mohn's rho: rec.	0.16				0.16			
Phi	0.83				0.81			
Bsp(1981)	20.8				21.1			
Bsp(2010)	4.1				4.1			
Bsp(2010)/Bsp(1981)	0.20				0.20			
M	0.3-0.6				0.3-0.6			
Recruitment	25.7	52.8			25.5	52.9		
Bsp(MSY)	2.0	4.1			1.7	3.5		
MSY	2.4	5.0			2.6	5.3		
σ_{comCAA}	0.10				0.10			
Survey	q $x10^6$	σ_{surv}	σ_{CAA}	ρ	q $x10^6$	σ_{surv}	σ_{CAA}	ρ
NEFSCspr	285.2	0.31	0.10	0.06	0.10	0.31	0.11	0.03
NEFSCfall	936.6	0.47	0.15	0.67	0.17	0.50	0.13	0.69
NEFSCwinter	233.5	0.30	0.19	0.21	0.14	0.30	0.19	0.18
MADFM	3.31	0.41	0.15	0.51	2.61	0.42	0.15	0.52
RIDFW	0.57	0.51	0.16	0.20	0.52	0.51	0.16	0.19
CTDEP	3.13	0.51	0.12	0.68	2.30	0.50	0.12	0.68
NY	0.11	0.92	0.20	0.28	0.11	0.92	0.20	0.29
NJDFW Ocean	4.13	0.42	0.16	-0.03	2.80	0.43	0.16	-0.03
NJDFW River	0.39	0.27	0.18	0.58	0.28	0.28	0.18	0.67
MADFM YOY	0.01	0.44	-	0.50	0.01	0.44	-	0.45
CTDEP YOY	0.24	0.65	-	0.26	0.21	0.72	-	0.33
RIDFW YOY	0.48	0.71	-	0.52	0.43	0.91	-	0.33
NY YOY	0.14	1.33	-	0.60	0.14	1.33	-	0.60
DEDFW YOY	0.00	1.00	-	-0.23	0.00	1.00	-	-0.18
URIGSO	0.53	0.51	0.13	0.31	0.55	0.44	0.13	0.20
σ_R_out (81-88, 89-10)	0.27	0.26			0.27	0.27		

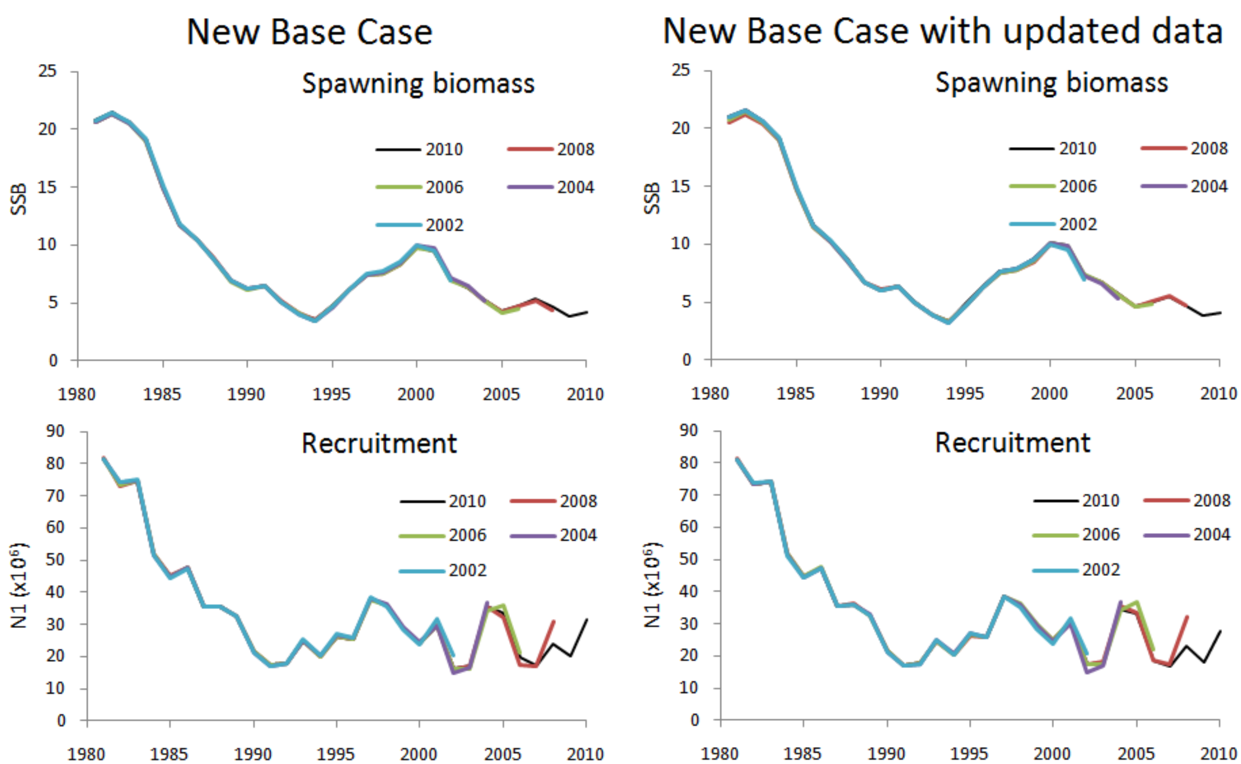

Fig. 1: Retrospective analysis of spawning biomass and recruitment for the two cases.

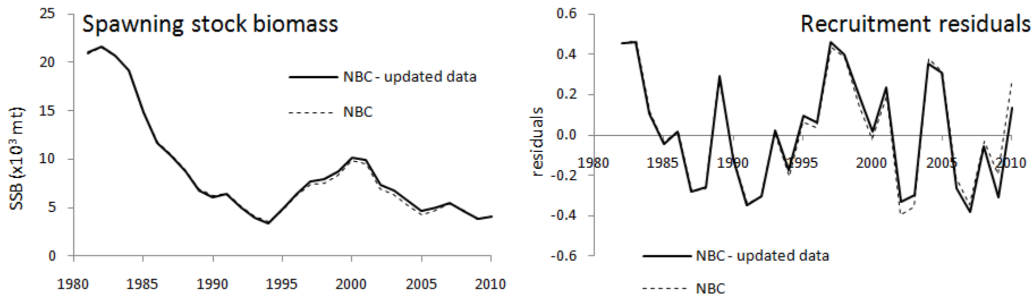

Fig. 2: Spawning stock biomass and recruitment trajectories for the New Base Case and New Base Case with updated data.

APPENDIX A – Data

In the Tables below, the data that are new or have been updated compared to those used in Rademeyer and Butterworth (2011) are shown in bold. The data tables used in Rademeyer and Buttterworth (2011) that have not been updated at all are not repeated here.

Table A1: Total catch (metric tons) for SNE/MA winter flounder (Terceiro, 2011). Pre-1981, only the commercial landings are available; to compute the total catches, the average 1981-1985 ratio of commercial landings (0.62), commercial discards (0.09), recreational landings (0.28) and recreational discards (0.01) is assumed to apply over the pre-1981 period.

Year	Total catch (mt)	Year	Total catch (mt)	Year	Total catch (mt)
1964	*12053*	1980	*17138*	1996	3702
1965	*13995*	1981	15764	1997	4483
1966	*19315*	1982	14143	1998	3614
1967	*15285*	1983	13582	1999	3745
1968	*11402*	1984	15526	2000	4754
1969	*13074*	1985	13891	2001	5147
1970	*13874*	1986	9217	2002	3412
1971	*11881*	1987	9352	2003	2827
1972	*8370*	1988	8795	2004	1942
1973	*8988*	1989	6915	2005	1563
1974	*6869*	1990	5999	2006	2023
1975	*6422*	1991	6842	2007	**1883**
1976	*5266*	1992	4729	2008	**1432**
1977	*7117*	1993	4311	2009	**639**
1978	*10204*	1994	3092	2010	**400**
1979	*10552*	1995	3434		

Table A2. Catch at age matrix (000s) for SNE/MA winter flounder (Terceiro, 2011).

	1	2	3	4	5	6	7+
1981	1380	14183	14401	3608	666	182	111
1982	575	14153	12374	3713	608	212	202
1983	616	7232	13273	6111	1791	695	544
1984	493	11470	13940	4890	1770	873	803
1985	274	7342	12771	6013	2922	1819	1404
1986	216	6327	9101	4218	1053	442	357
1987	74	5265	8988	3084	2690	751	424
1988	85	3946	9401	3963	1206	978	303
1989	468	5275	7208	3541	861	226	214
1990	36	2110	6276	2933	768	196	142
1991	52	3029	7146	3349	860	252	113
1992	25	1507	4460	2582	673	162	53
1993	292	2200	3520	1897	714	188	138
1994	251	2612	2339	1280	337	97	39
1995	88	654	3112	2202	506	83	20
1996	171	1050	3289	2181	556	129	40
1997	88	1841	3488	2252	584	96	39
1998	16	1371	3043	1788	555	185	74
1999	5	2146	4062	1577	375	82	18
2000	43	1336	3436	2473	822	146	72
2001	35	1689	3503	2274	883	231	124
2002	14	478	1897	1830	925	324	115
2003	15	498	1802	1199	501	223	136
2004	36	378	999	858	331	223	167
2005	32	417	765	755	328	134	81
2006	39	758	1598	686	277	133	108
2007	**7**	**335**	**1460**	**1010**	**290**	**84**	**42**
2008	**34**	**243**	**699**	**725**	**278**	**126**	**66**
2009	**83**	**195**	**271**	**268**	**211**	**66**	**30**
2010	**67**	**87**	**150**	**159**	**87**	**52**	**35**

Table A3. Total fishery mean weights-at-age (kg) for SNE/MA winter flounder (M. Terceiro, pers. commn).

	1	2	3	4	5	6	7+
1981	0.129	0.274	0.477	0.798	1.063	1.242	1.196
1982	0.092	0.263	0.440	0.697	1.052	1.257	1.840
1983	0.197	0.237	0.354	0.517	0.768	1.047	1.552
1984	0.148	0.261	0.370	0.546	0.695	0.915	1.284
1985	0.111	0.282	0.364	0.482	0.522	0.467	0.613
1986	0.129	0.292	0.398	0.480	0.685	0.879	0.961
1987	0.046	0.287	0.384	0.551	0.475	0.564	0.853
1988	0.039	0.279	0.351	0.508	0.634	0.517	0.827
1989	0.118	0.258	0.378	0.508	0.660	0.716	1.073
1990	0.082	0.295	0.394	0.525	0.672	0.808	0.990
1991	0.093	0.317	0.420	0.534	0.603	0.823	1.168
1992	0.079	0.287	0.427	0.599	0.802	0.945	1.395
1993	0.169	0.334	0.460	0.592	0.689	0.878	1.167
1994	0.162	0.311	0.429	0.550	0.750	0.985	1.281
1995	0.267	0.420	0.470	0.559	0.789	1.089	1.741
1996	0.136	0.380	0.464	0.607	0.824	0.851	1.085
1997	0.245	0.443	0.515	0.644	0.771	0.957	1.477
1998	0.196	0.362	0.465	0.568	0.665	1.090	1.116
1999	0.136	0.359	0.439	0.524	0.684	0.903	1.147
2000	0.106	0.407	0.492	0.622	0.729	0.975	1.079
2001	0.089	0.436	0.519	0.640	0.783	1.051	1.234
2002	0.135	0.372	0.499	0.617	0.747	0.927	1.143
2003	0.167	0.426	0.517	0.672	0.854	1.000	1.135
2004	0.094	0.384	0.549	0.619	0.786	0.945	1.251
2005	0.129	0.342	0.488	0.675	0.834	1.013	1.318
2006	0.118	0.379	0.468	0.652	0.872	1.065	1.289
2007	0.065	0.388	0.473	0.634	0.861	1.097	1.372
2008	0.110	0.355	0.477	0.597	0.754	0.939	1.238
2009	0.126	0.326	0.434	0.594	0.757	1.006	0.941
2010	**0.127**	**0.329**	**0.505**	**0.615**	**0.766**	**0.899**	**1.075**

Table A4: Survey data in terms of total numbers for SNE/MA winter flounder (Terceiro, 2011). The NEFSC survey units have changed (now given as stratified mean number per tow instead of mean total number), but only the 2010 data points are new.

	NEFSC spring	NEFSC fall	NEFSC winter	MADMF	RIDFW	CTDEP	NYDEC	NJDFW Ocean	NJDFW Rivers	URIGSO	YOY-MADMF	YOY-CTDEP	YOY-RIDFW	YOY-NYDEC	YOY-DEDFW
Month	4	10	3	5	5	5	5	5	5	5	1	1	1	1	1
Ages	1-7+	2-6+	1-5+	1-7+	1-7+	1-7+	1-2+	1-7+	1-7+	1-7+	1	1	1	1	1
1981	9.02	10.21	-	47.80	87.98	-	-	-	-	0.43	-	-	-	-	-
1982	6.99	4.93	-	41.46	30.95	-	-	-	-	0.34	-	-	-	-	-
1983	6.26	8.76	-	58.14	58.95	-	-	-	-	0.37	-	-	-	-	-
1984	5.52	2.68	-	38.02	41.64	111.96	-	-	-	0.23	-	-	-	-	-
1985	5.36	2.73	-	39.49	34.98	83.57	3.35	-	-	0.32	-	-	1.52	-	35.04
1986	2.27	1.54	-	36.78	41.02	63.65	-	-	-	0.34	-	29.00	-	-	25.87
1987	1.76	1.17	-	39.16	56.22	79.93	3.43	-	-	0.33	-	11.60	2.67	0.17	65.05
1988	2.13	1.25	-	28.36	34.44	137.59	2.88	-	-	0.27	-	9.19	1.47	0.09	55.21
1989	2.49	1.44	-	27.38	20.88	148.19	5.89	-	-	0.18	15.46	18.92	11.20	0.02	**36.44**
1990	1.99	1.98	-	27.72	20.44	223.09	3.70	-	-	0.42	1.90	21.48	8.73	0.29	**20.12**
1991	2.47	1.95	-	11.02	40.97	150.21	6.94	-	-	0.33	2.85	12.19	14.72	0.63	16.80
1992	1.58	2.96	3.68	28.96	4.41	61.38	2.24	-	-	0.27	5.23	33.33	76.87	0.03	11.89
1993	0.96	1.38	2.59	50.40	2.92	63.59	14.24	19.17	-	0.29	11.90	5.29	17.10	0.27	19.06
1994	1.51	4.13	3.80	50.84	10.26	84.45	7.28	14.06	-	0.07	5.61	2.52	14.93	0.04	12.44
1995	2.10	2.25	2.22	37.37	32.19	50.12	4.11	30.41	2.82	0.15	14.23	5.64	4.10	0.31	57.63
1996	1.52	3.19	3.78	30.92	20.68	110.61	2.99	9.40	3.05	0.15	10.10	6.22	16.25	0.10	41.20
1997	1.44	7.89	3.91	38.51	22.27	71.31	6.56	36.02	3.35	0.22	19.22	4.70	4.42	0.04	43.05
1998	2.77	6.60	7.17	35.88	19.22	72.90	4.09	18.20	4.25	0.39	7.47	2.56	3.11	0.10	26.97
1999	4.17	3.60	10.33	25.98	13.46	41.35	3.47	17.79	3.23	0.17	9.24	14.97	7.52	0.13	13.24
2000	3.17	6.17	5.57	24.64	16.32	45.42	1.71	10.10	2.11	0.20	8.70	53.00	0.90	0.07	14.64
2001	1.57	4.88	3.10	15.79	12.49	54.51	5.69	13.83	2.84	0.35	4.33	13.73	2.31	0.08	**16.70**
2002	2.04	8.86	2.90	6.70	11.56	43.72	0.36	22.58	2.80	0.21	1.34	18.12	0.07	0.06	9.96
2003	0.77	3.21	2.20	17.73	5.56	27.84	0.54	12.52	1.57	0.10	3.06	31.22	0.86	0.01	19.71
2004	1.24	3.36	4.34	11.14	11.16	20.46	5.49	14.21	1.27	0.20	8.07	18.72	0.50	0.28	25.81
2005	0.93	3.71	4.05	27.02	15.74	16.10	-	25.67	**0.99**	0.10	10.96	5.28	-	0.20	30.75
2006	1.81	2.95	5.08	17.63	15.36	5.58	-	18.13	-	0.08	5.63	12.72	-	0.02	10.82
2007	0.94	3.48	2.79	16.68	7.33	28.66	0.15	18.58	-	0.16	0.93	14.17	1.11	0.15	8.54
2008	1.81	2.86	-	10.63	7.36	24.12	-	12.01	-	0.17	4.73	11.65	-	0.05	27.03
2009	0.99	1.78	-	14.58	3.67	22.64	-	**13.98**	-	0.09	1.97	10.77	-	0.02	11.54
2010	**0.97**	**2.65**	-	29.84	11.56	**20.88**	-	**7.99**	-	0.08	**0.78**	**1.52**	-	**0.04**	12.31

Table A6: Survey catch-at-age data mean numbers for SNE/MA winter flounder (Terceiro, 2011). The NEFSC survey units have changed (now given as stratified mean number per tow instead of mean total number), but only the 2010 data points are new.

NEFSC spring

	1	2	3	4	5	6	7+
1981	0.99	4.00	3.41	0.47	0.13	0.01	0.01
1982	1.16	3.20	1.56	0.74	0.21	0.09	0.03
1983	0.58	0.97	2.14	1.23	0.81	0.37	0.16
1984	0.22	1.36	2.18	0.85	0.46	0.29	0.16
1985	0.41	1.21	2.16	0.72	0.51	0.20	0.15
1986	0.10	0.49	1.16	0.31	0.15	0.05	0.01
1987	0.14	0.54	0.70	0.28	0.06	0.02	0.02
1988	0.09	0.48	0.99	0.37	0.16	0.02	0.02
1989	0.14	0.95	0.90	0.34	0.11	0.02	0.03
1990	0.23	0.49	0.89	0.28	0.05	0.04	0.01
1991	0.14	0.60	1.22	0.41	0.05	0.02	0.03
1992	0.14	0.39	0.62	0.36	0.05	0.02	0.00
1993	0.14	0.35	0.26	0.12	0.07	0.01	0.01
1994	0.16	0.74	0.43	0.11	0.04	0.02	0.01
1995	0.22	0.75	0.87	0.22	0.03	0.00	0.01
1996	0.07	0.54	0.66	0.17	0.06	0.01	0.01
1997	0.13	0.50	0.56	0.18	0.06	0.01	0.00
1998	0.33	1.21	0.72	0.37	0.13	0.01	0.00
1999	0.41	1.89	1.35	0.36	0.11	0.04	0.01
2000	0.28	0.70	1.19	0.65	0.27	0.07	0.01
2001	0.17	0.26	0.47	0.44	0.20	0.02	0.01
2002	0.11	0.60	0.56	0.38	0.23	0.11	0.05
2003	0.12	0.11	0.33	0.10	0.05	0.04	0.02
2004	0.30	0.19	0.29	0.26	0.11	0.05	0.04
2005	0.10	0.45	0.11	0.16	0.07	0.03	0.01
2006	0.30	0.62	0.62	0.16	0.08	0.02	0.01
2007	0.11	0.14	0.36	0.26	0.04	0.01	0.02
2008	0.18	0.61	0.48	0.41	0.11	0.01	0.01
2009	0.06	0.22	0.30	0.16	0.18	0.05	0.02
2010	**0.21**	**0.24**	**0.30**	**0.14**	**0.07**	**0.01**	**0.00**

NEFSC fall

	2-	3	4	5	6+
1981	7.16	2.49	0.30	0.10	0.12
1982	2.97	1.34	0.47	0.12	0.02
1983	5.45	2.06	0.62	0.35	0.28
1984	1.21	1.17	0.26	0.03	0.01
1985	1.34	0.99	0.30	0.09	0.01
1986	1.13	0.36	0.03	0.01	0.01
1987	0.67	0.36	0.12	0.02	0.00
1988	0.33	0.64	0.22	0.04	0.02
1989	1.11	0.26	0.05	0.01	0.01
1990	0.97	0.85	0.15	0.01	0.00
1991	1.09	0.73	0.12	0.01	0.00
1992	1.87	0.79	0.26	0.03	0.01
1993	0.95	0.35	0.08	0.00	0.00
1994	2.68	1.08	0.30	0.04	0.03
1995	1.51	0.63	0.09	0.01	0.01
1996	2.01	0.80	0.31	0.06	0.01
1997	5.06	2.20	0.55	0.08	0.00
1998	4.22	1.91	0.41	0.05	0.01
1999	1.38	1.46	0.54	0.18	0.04
2000	3.20	2.02	0.71	0.22	0.02
2001	2.28	1.61	0.63	0.30	0.06
2002	4.53	2.35	1.14	0.59	0.20
2003	1.46	1.15	0.46	0.10	0.04
2004	2.68	0.28	0.28	0.06	0.06
2005	2.55	0.73	0.21	0.13	0.09
2006	1.86	0.79	0.22	0.06	0.02
2007	2.24	1.03	0.16	0.02	0.03
2008	1.18	0.70	0.62	0.29	0.07
2009	1.29	0.23	0.15	0.09	0.02
2010	**1.51**	**0.66**	**0.23**	**0.19**	**0.06**

NEFSC winter

	1	2	3	4	5+
1992	0.73	0.86	1.09	0.73	0.28
1993	0.56	1.16	0.54	0.18	0.15
1994	0.36	1.16	1.76	0.25	0.28
1995	0.04	0.75	1.26	0.17	0.00
1996	1.01	0.87	1.55	0.32	0.02
1997	0.43	1.49	1.32	0.54	0.13
1998	0.42	3.52	1.95	0.96	0.32
1999	0.84	5.94	2.23	0.96	0.36
2000	0.23	2.82	2.12	0.24	0.16
2001	1.04	0.55	0.70	0.54	0.27
2002	0.08	1.34	0.74	0.15	0.59
2003	0.09	0.57	1.04	0.25	0.25
2004	2.17	1.02	0.43	0.36	0.36
2005	0.39	2.56	0.36	0.43	0.31
2006	0.00	2.40	1.73	0.51	0.44
2007	0.02	0.56	1.03	1.03	0.15

CTDEP

	1	2	3	4	5	6	7+
1984	8.21	44.01	31.83	20.96	4.23	1.23	1.49
1985	4.11	28.46	32.88	14.17	2.33	0.82	0.8
1986	6.69	26	15.53	12.26	2.05	0.5	0.62
1987	7.32	44.69	14.56	5.05	6.55	1.28	0.48
1988	14.49	71.87	39.1	8.59	1.83	1.46	0.25
1989	13.56	78.43	41.23	10.85	2.84	0.98	0.3
1990	11.31	131.52	64.97	8.97	4.09	1.96	0.27
1991	8.52	66.99	60.39	9.31	4.05	0.8	0.15
1992	6.8	31.32	12.78	8.97	1.1	0.36	0.05
1993	19.11	19.87	15.46	4.81	3.24	0.8	0.3
1994	9.57	64.14	5.86	3.01	1.14	0.49	0.24
1995	14.35	23.69	9.77	1.36	0.63	0.2	0.12
1996	11.46	59.07	24.17	14.41	0.97	0.28	0.25
1997	12.53	25.53	19.41	9.45	3.76	0.51	0.12
1998	11.22	32.4	12.23	12.67	3.15	0.99	0.24
1999	6.56	12.42	11.27	6.09	3.2	1.14	0.67
2000	7.11	16.66	8.4	7.7	3.42	1.53	0.6
2001	8.45	19.6	10.85	8.06	5.46	1.28	0.81
2002	6.27	19.9	9.56	4.43	1.95	1.02	0.59
2003	2.47	7.83	8.71	4.79	1.95	0.77	1.32
2004	6.34	3.84	3.49	3.88	1.91	0.64	0.36
2005	7.06	6.18	0.84	0.81	0.67	0.21	0.33
2006	1.14	2.6	1.1	0.19	0.14	0.17	0.24
2007	2.98	10.83	10.7	3.1	0.61	0.15	0.29
2008	11.48	3.48	4.19	4.12	0.65	0.12	0.08
2009	7.56	11.21	1.02	1.31	1.21	0.22	0.06
2010	**6.64**	**8.45**	**3.94**	**0.71**	**0.57**	**0.44**	**0.13**

NJDFW Ocean

	1	2	3	4	5	6	7+
1993	5.1	6.5	2.5	2.4	1.7	0.4	0.57
1994	3.7	4.2	3.9	1.4	0.4	0.3	0.16
1995	8	10.1	8.6	2.4	0.9	0.3	0.11
1996	0.6	2.9	2.6	1.9	0.9	0.3	0.2
1997	16.6	5.4	6.1	6	1.5	0.3	0.12
1998	4.5	3.9	4.8	3.3	1.2	0.4	0.1
1999	2.4	2.2	5.9	3.1	2.9	0.7	0.59
2000	0.7	0.3	2.1	3.3	2	0.9	0.8
2001	3.9	0.6	1.3	2.7	3.8	0.7	0.83
2002	5.81	3.21	4.55	2.22	2.8	2.16	1.83
2003	2.08	1.1	4.79	1.24	1.09	0.87	1.35
2004	6.48	0.72	1.42	2.08	0.56	1.38	1.57
2005	4.97	10.04	2.55	2.76	2.61	1.32	1.42
2006	0.64	2.49	9.43	3.23	0.62	0.75	0.97
2007	3.8	0.67	4.33	6.09	1.51	0.62	1.56
2008	5.57	1.59	0.83	1.75	1.69	0.21	0.37
2009	**2.84**	**4.35**	**3.54**	**1.34**	**1.48**	**0.33**	**0.1**
2010	**0.75**	**1.59**	**2.63**	**1.5**	**0.94**	**0.37**	**0.21**

Initial Applications of Statistical Catch-at-Age Assessment Methodology to the Gulf of Maine Winter Flounder Resource

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Abstract

Application of SCAA to the Gulf of Maine flounder resource, though initial at this stage, suggests that with some downweighting of catch-at-age data in the likelihood, the serious retrospective problem of previous VPA assessments of this resource disappear. There are indications from the model fits considered that survey selectivity is domed (assuming commercial selectivity to be asymptotically flat at higher ages) and/or natural mortality is higher than the conventionally assumed 0.2.

Introduction

This paper presents the results of some initial applications of Statistical Catch-at-Age methodology to data for the Gulf of Maine winter flounder resource.

Data and Methodology

The catch and survey based data (including catch-at-age information) and some biological data are listed in Tables in Appendix A, from Nitschke (2011).

The details of the SCAA assessment methodology are provided in Appendix B. The Beverton-Holt stock-recruitment steepness h is fixed at 0.9 for the analyses that follow. The contribution of all catch-at-age data to the negative log-likelihood is down-weighted by a multiplicative factor w^{CAA}.

Results and Discussion

Case 1: Base Case with w^{CAA}=0.1, M=0.2 and commercial selectivity-at-age flat for ages 5 and above. (Figs 1-5)
Particular reasons for this choice were to not have all selectivities domed, and especially the fact that unlike the GARM3 VPA assessment (Nitschke, 2008) there is virtually no retrospective pattern (Fig. 5). Note (Fig. 1) that the spawning biomass estimates are much greater than for that GARM3 VPA. The survey selectivities are domed (Fig. 3) and fit the CAA data well, but forcing the commercial selectivity to be flat leads to systematic overestimation of the commercial plus-group numbers by the model (Fig. 4).

Case 2: Split the commercial selectivity vector estimation between 1997 and 1998
This split makes very little difference to the results; hence no plts are shown.

Case 3: Force selectivity at age for the NEFSC surveys to be flat from age 5 and above (Fig. 6)
This leads to an appreciable deterioration to the for to the data: -lnL increases by 13. The primary reason for this deterioration is evident from the CAA residual plots in Fig. 6, which show a poor fit to the plus group proportions at age for the two NEFSC surveys.

Case 4: Fix natural mortality $M = 0.4$ (Fig. 7)
This leads to a 6 point improvement in the log-likelihood for the fit, with reduced residuals for the plus group for the commercial CAA data.

Case 5: Estimate a (constant) M bounded above by 0.6 (Fig. 8)
The estimated M hits the upper constraint of 0.6. There is a further improvement in the negative log-likelihood of 3 points, with the residuals for the plus group for the commercial CAA data reduced to near zero. Spawning biomass is however estimated to be lower in circumstances of an increased estimate for the pre-exploitation level.

Case 6: Force selectivities-at-age for all surveys to be flat above age 5 (Fig. 9)
This leads to further appreciable increases in –lnL, and further deterioration in the fits to the plus group proportions in the CAA for all data sets.

Case 7: Different weightings ($w^{survCAA}$) for the survey CAA data in the likelihood (Figs 10-12), where the reference alternative value for $w^{survCAA}$ is 0.3 (results in Table 1 are shown for this choice) in place of the 0.1 for the Base Case, but results for additional choices for $w^{survCAA}$ are shown in Fig. 11.
Results are qualitatively different for $w^{survCAA} = 0.3$, with substantial deterioration in the fits to trends in the survey abundance series (Fig. 10) and a bad retrospective pattern (Fig. 12). Fig 11 shows how as $w^{survCAA}$ is increased the fit moves closer to the VPA solution, but with a large jump between $w^{survCAA}$ values of 0.27 and 0.28 which is suggestive of a multi-modal likelihood and some conflict between the survey trend and CAA data.

Case 8: Allowance for doming in the commercial as well as the survey selectivity vectors (Fig. 13)
Unsurprisingly the negative log-likelihood improves, and the commercial plus group proportions for the CAA data are better fitted. The estimated magnitude of the spawning biomass increases markedly.

Concluding remarks

This does not pretend to be a comprehensive analysis, but some important points nevertheless seem reasonably established:

- Survey selectivity must be domed (though to a lesser extent as M might be set higher than 0.2).
- There is some conflict between the CAA data and the trends in the survey estimates, but if the former are given lower weight, their fit to the data does not appear visually to deteriorate substantially.
- Downweighting of the CAA data leads to higher estimated abundance, but also to the disappearance of the retrospective pattern that marks the VPA results.

References

Nitschke P. 2008. I. Gulf of Maine winter flounder. Appendix to the Report of the 3rd Groundfish Assessment Review Meeting (GARM III): Assessment of 19 Northeast Groundfish Stocks through 2007, Northeast Fisheries Science Center, Woods Hole, Massachusetts, August 4-8, 2008 http://www.nefsc.noaa.gov/publications/crd/crd0816/pdfs/garm3i.pdf

Nitschke P. 2011. Working paper (Nitschke, pers. comm)

Table 1: Results of SCAA for the Gulf of Maine winter flounder – see main text and Appendix B for specifications and definitions of some of the symbols used. Biomass units are '000t. Values input rather than estimated are shown in bold.

	1) Base Case (BC)	2) Case 2: as BC but two commercial selectivity periods	3) Case 3: as BC but NEFSC surveys selectivity flat from age 5	4) Case 4: as BC but M=0.4 throughout	5) Case 5: as BC but M estimated	6) Case 6: as BC but flat selectivity from age 5 for all surveys	7) Case 7: as Case 6 but weight of survey CAA likelihood is 0.3 instead of 0.1	8) as BC but commercial selectivity domed
'-lnL:overall	-123.2	-123.5	-110.1	-129.1	-132.3	-101.3	-156.9	-133.5
'-lnL:Survey	-72.4	-72.4	-71.6	-72.4	-72.7	-79.5	1.8	-72.8
'-lnL:CAA	8.0	7.4	7.2	2.3	-0.1	7.8	-1.6	-1.9
'-lnL:CAAsurv	-42.7	-42.8	-29.0	-42.4	-42.9	-14.4	-142.5	-42.6
'-lnL:RecRes	-17.2	-17.2	-17.4	-17.1	-17.0	-15.8	-14.9	-17.1
'-lnL:SelSmoothing	1.0	1.5	0.7	0.6	0.4	0.5	0.3	0.9
h	**0.90**	**0.90**	**0.90**	**0.90**	**0.90**	**0.90**	**0.90**	**0.90**
M	**0.20**	**0.20**	**0.20**	**0.40**	**0.60**	**0.20**	**0.20**	**0.20**
Theta	0.50	0.54	0.35	0.79	0.25	0.25	0.41	0.62
Phi	0.12	0.11	0.19	0.08	0.34	0.30	0.30	0.15
ρ_{SR}	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ksp	37.97	37.90	38.98	20.35	55.94	41.00	23.09	53.06
B^{sp}_{2010}	15.88	15.98	15.78	11.39	10.33	16.46	4.73	23.53
B^{sp}_{2010}/K^{sp}	0.42	0.42	0.40	0.56	0.18	0.40	0.20	0.44
$B^{sp}_{2010}/B^{sp}_{1982}$	0.83	0.79	1.15	0.71	0.73	1.64	0.50	0.72
$MSYL^{sp}$	0.17	0.17	0.17	0.15	0.15	0.17	0.17	0.14
B^{sp}_{MSY}	6.33	6.43	6.56	3.10	8.42	6.93	3.94	7.18
MSY	1.89	1.97	1.98	2.59	7.24	2.09	1.21	2.37
σ_{comCAA}	0.21	0.21	0.21	0.17	0.15	0.21	0.14	0.14

	1) q x10^6	1) σ_{surv}	1) σ_{CAA}	2) q x10^6	2) σ_{surv}	2) σ_{CAA}	3) q x10^6	3) σ_{surv}	3) σ_{CAA}	4) q x10^6	4) σ_{surv}	4) σ_{CAA}
Survey	q x10^6	σ_{surv}	σ_{CAA}	q x10^6	σ_{surv}	σ_{CAA}	q x10^6	σ_{surv}	σ_{CAA}	q x10^6	σ_{surv}	σ_{CAA}
NEFSCspring	0.31	0.55	0.15	0.31	0.54	0.15	0.29	0.57	0.21	0.20	0.55	0.16
NEFSCfall	0.45	0.46	0.16	0.46	0.46	0.16	0.42	0.47	0.23	0.30	0.46	0.16
MADspring	4.08	0.25	0.14	4.07	0.25	0.14	4.04	0.25	0.14	1.98	0.25	0.13
MADfall	4.32	0.17	0.12	4.33	0.17	0.12	4.26	0.17	0.13	2.26	0.17	0.13
σ_{R_out}	0.27			0.27			0.24			0.29		

	5) q x10^6	5) σ_{surv}	5) σ_{CAA}	6) q x10^6	6) σ_{surv}	6) σ_{CAA}	7) q x10^6	7) σ_{surv}	7) σ_{CAA}	8) q x10^6	8) σ_{surv}	8) σ_{CAA}
Survey	q x10^6	σ_{surv}	σ_{CAA}	q x10^6	σ_{surv}	σ_{CAA}	q x10^6	σ_{surv}	σ_{CAA}	q x10^6	σ_{surv}	σ_{CAA}
NEFSCspring	0.18	0.54	0.16	0.27	0.58	0.22	0.71	0.63	0.16	0.22	0.55	0.15
NEFSCfall	0.24	0.47	0.16	0.40	0.46	0.24	0.94	0.72	0.15	0.31	0.46	0.16
MADspring	1.29	0.25	0.13	3.62	0.28	0.20	7.59	0.55	0.12	2.83	0.26	0.14
MADfall	1.31	0.17	0.13	3.89	0.12	0.19	8.30	0.58	0.12	3.01	0.17	0.13
σ_{R_out}	0.30			0.29			0.33			0.29		

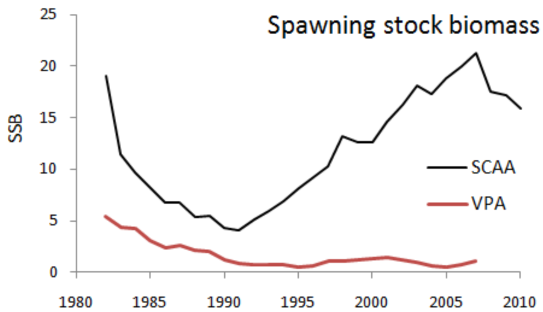

Fig. 1: Spawning stock biomass trajectories for the Base Case, compared to the GARM3 VPA (Nitschke, 2008).

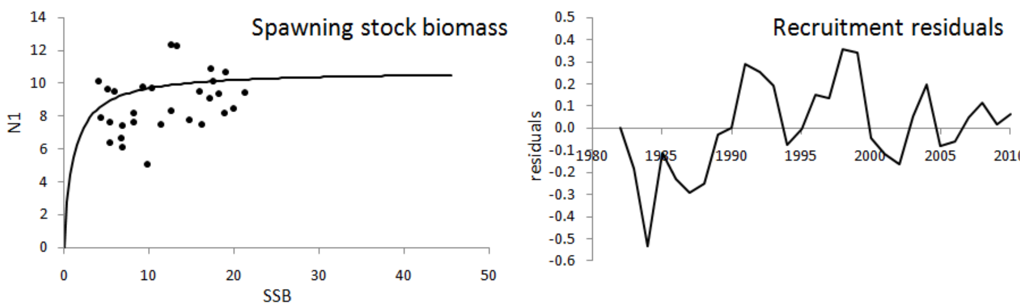

Fig. 2: Stock-recruit relationship and estimated stock-recruit residuals for the Base Case.

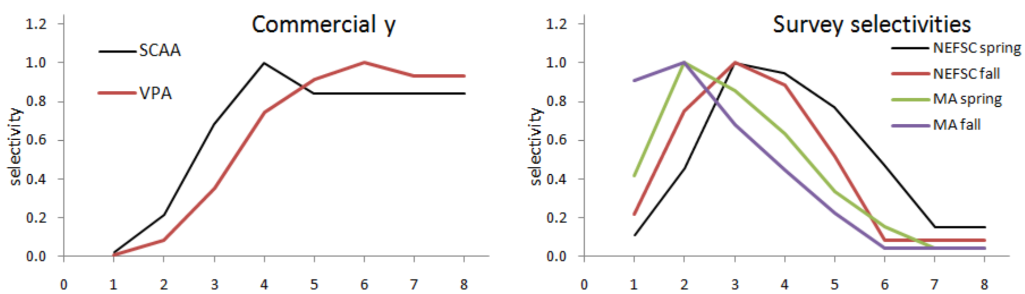

Fig. 3: Commercial and survey selectivities-at-age estimated for the Base Case.

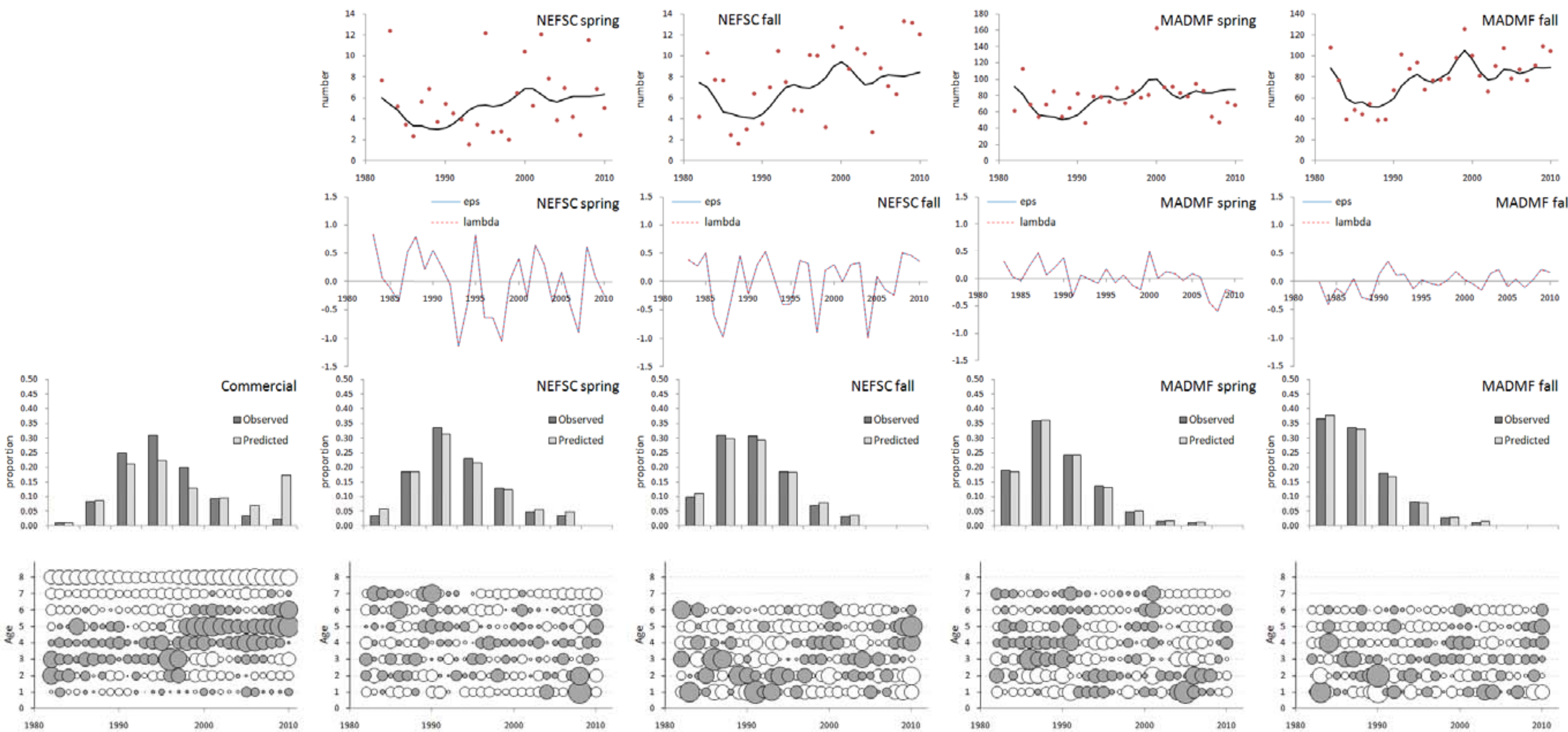

Fig. 4: The first two rows give the fit of the Base Case to the survey indices of abundance and corresponding survey standardised residuals. The third and fourth row plot the fit of the Base Case to the commercial and survey catch-at-age data. The third row compares the observed and predicted CAA as averaged over all years for which data are available, while the fourth row plots the standardised residuals, with the size (area) of the bubbles being proportional to the magnitude of the corresponding standardised residuals. For positive residuals, the bubbles are grey, whereas for negative residuals, the bubbles are white.

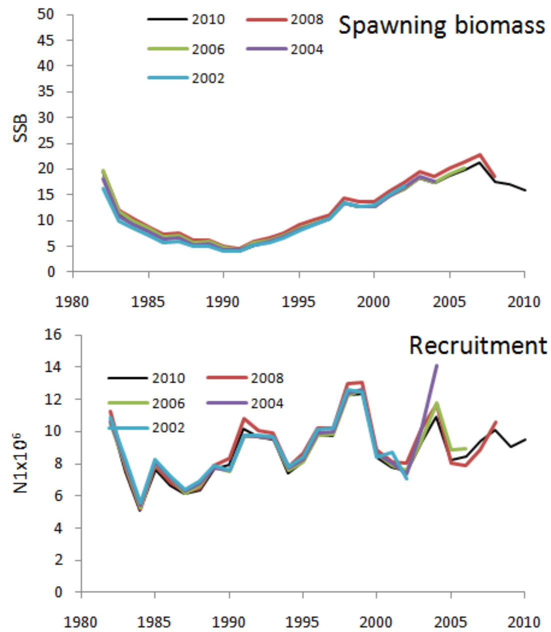

Fig. 5: Retrospective analysis of spawning biomass and recruitment for the Base Case.

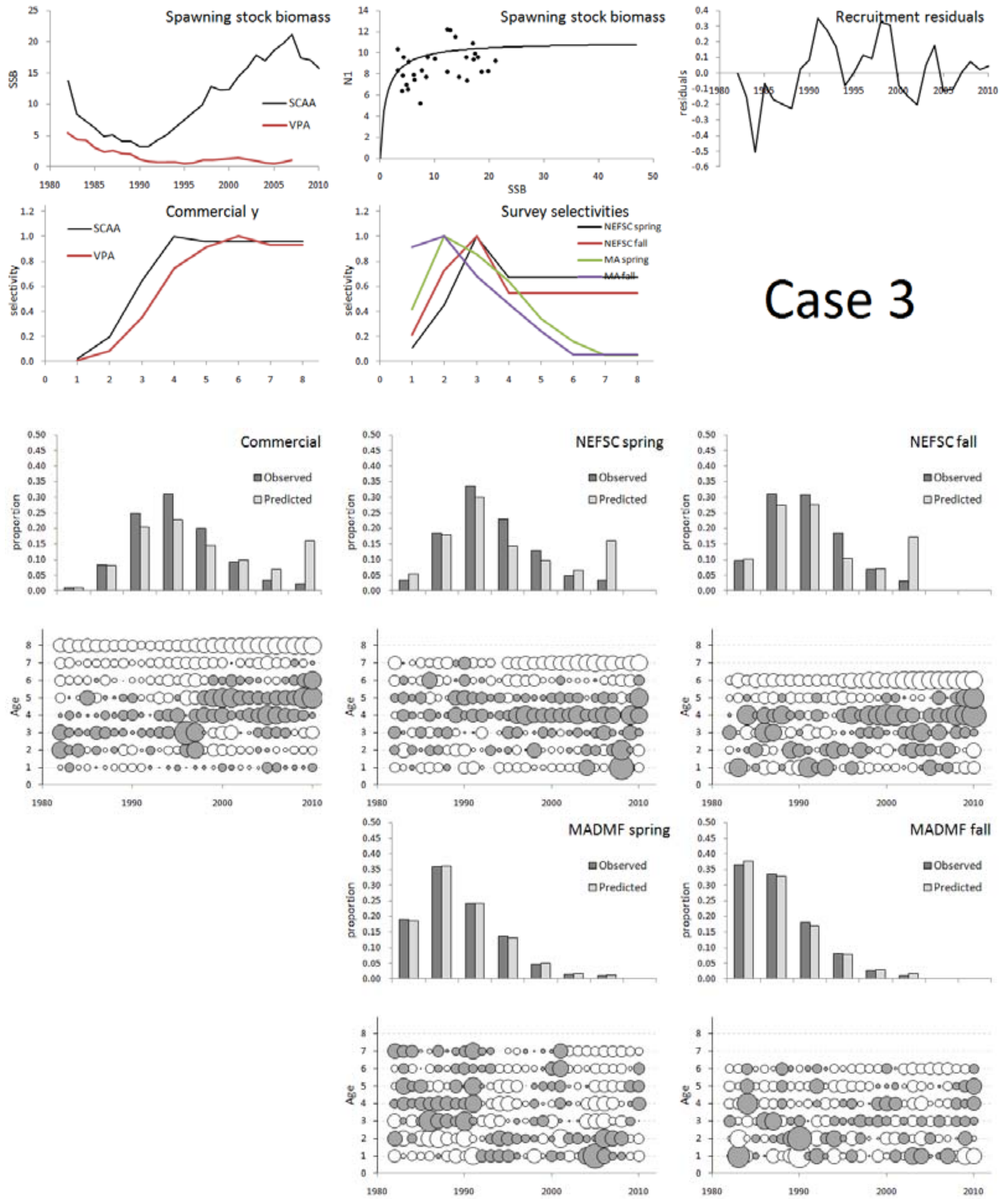

Fig. 6: Spawning stock biomass trajectories, stock-recruit relationship, recruitment residuals and selectivities for Case 3 (NEFSC survey selectivity flat). The fits to the commercial and survey CAA are also shown.

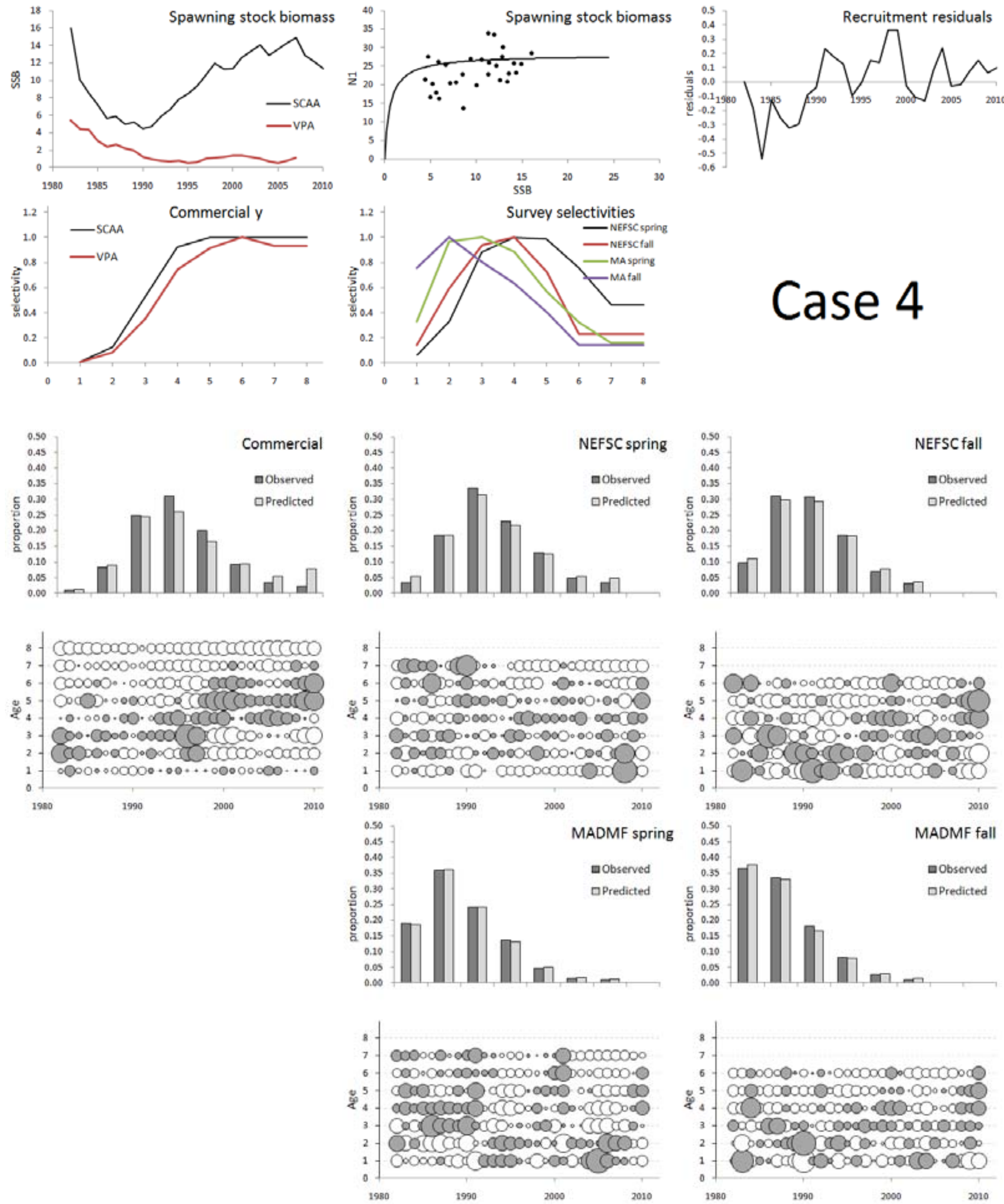

Fig. 7: Spawning stock biomass trajectories, stock-recruit relationship, recruitment residuals and selectivities for Case 4 (M = 0.4). The fits to the commercial and survey CAA are also shown.

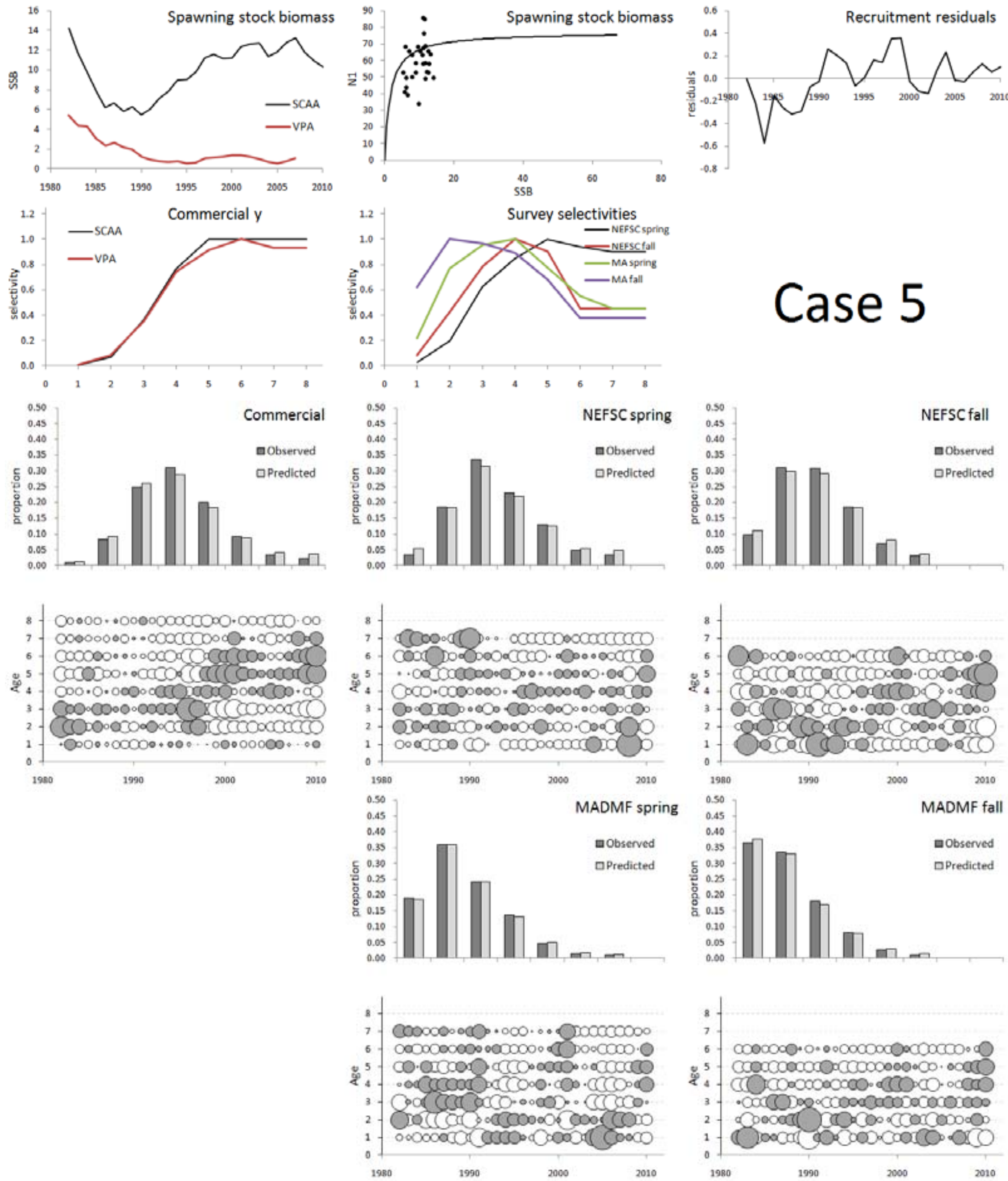

Fig. 8: Spawning stock biomass trajectories, stock-recruit relationship, recruitment residuals and selectivities for Case 5 (*M* estimated at 0.6). The fits to the commercial and survey CAA are also shown.

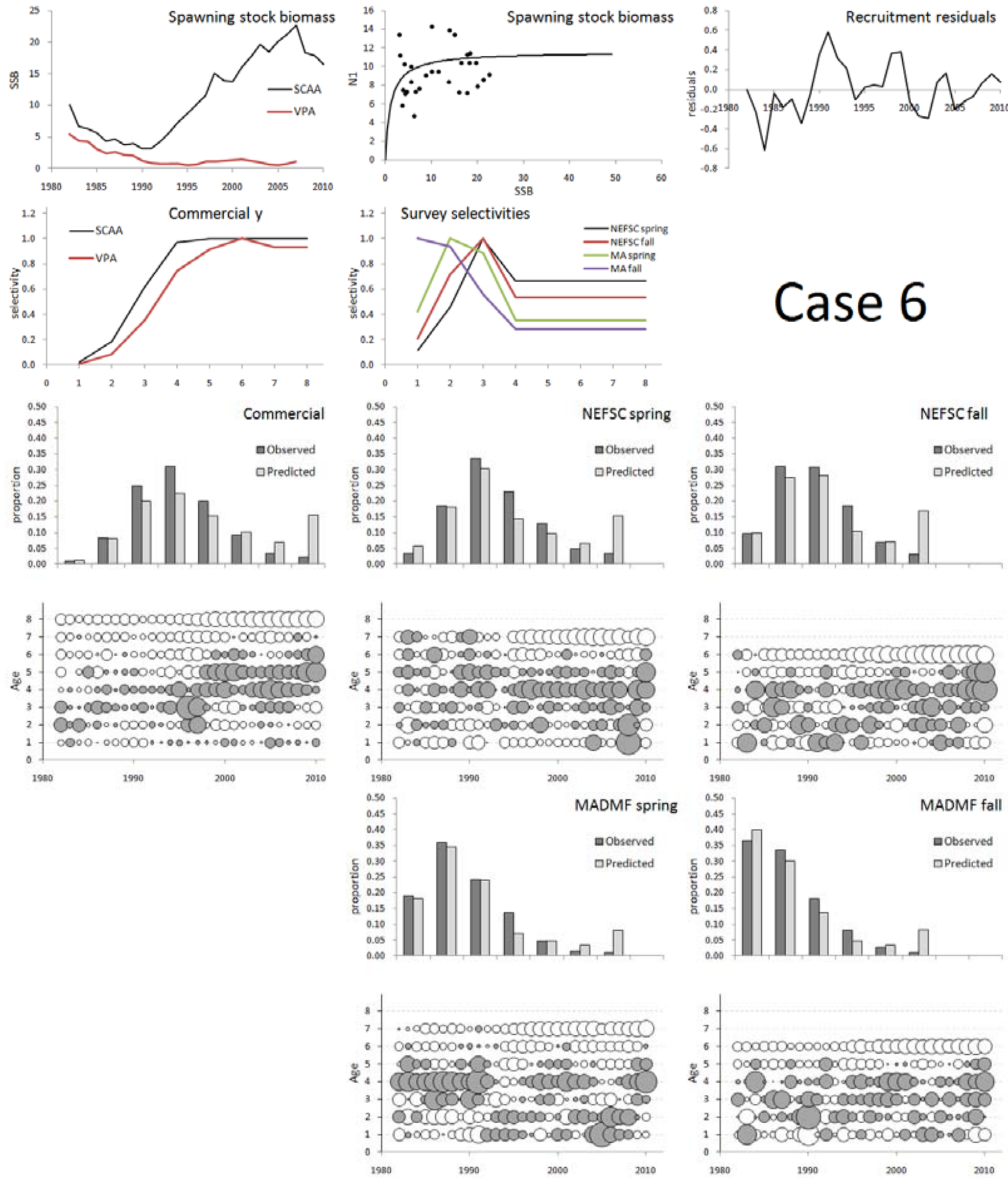

Fig. 9: Spawning stock biomass trajectories, stock-recruit relationship, recruitment residuals and selectivities for Case 6 (flat selectivities for all surveys). The fits to the commercial and survey CAA are also shown.

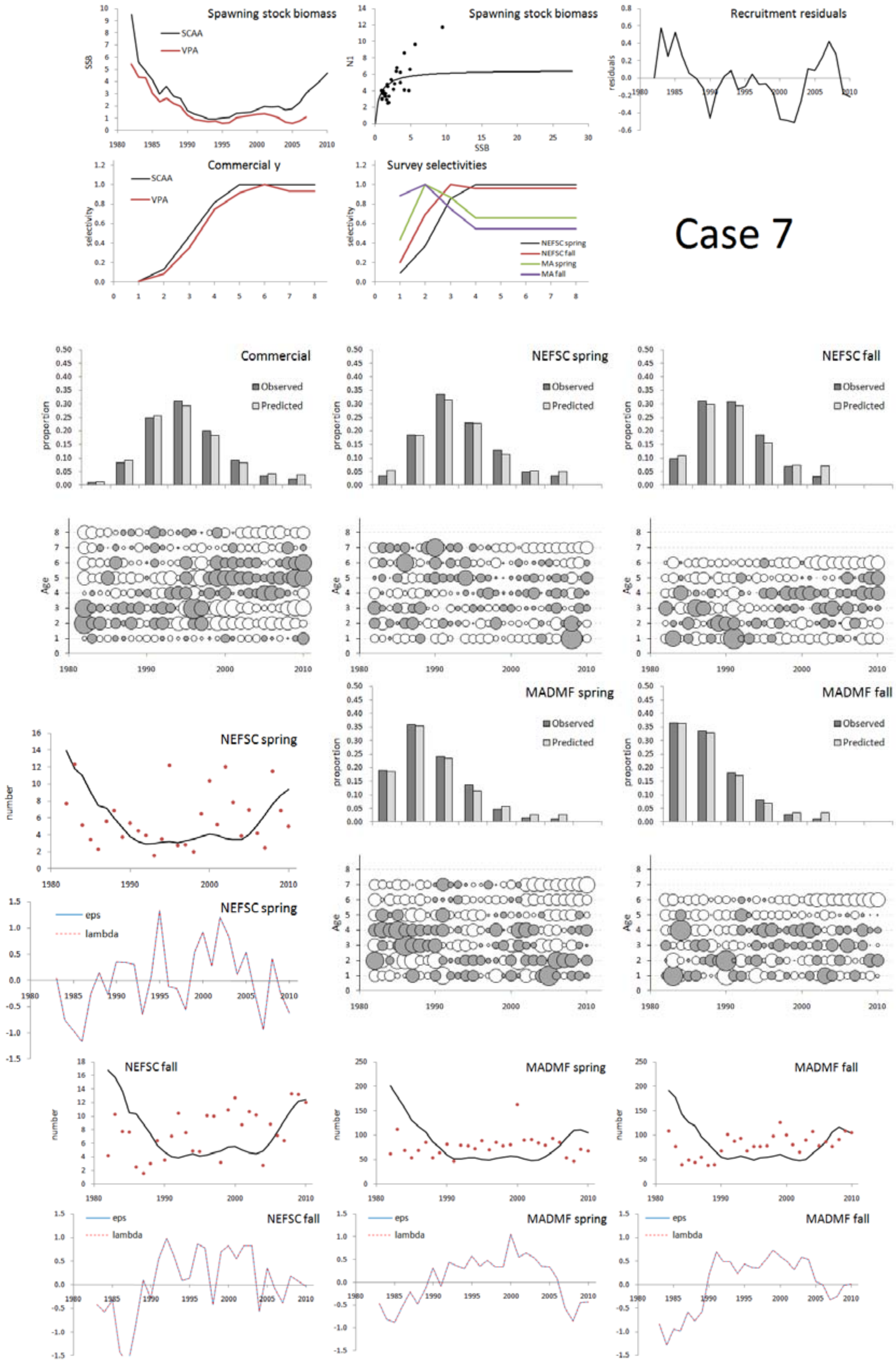

Fig. 10: Spawning stock biomass trajectories, stock-recruit relationship, recruitment residuals and selectivities for Case 7 (survey CAA data upweighted in the likelihood). The fits to the commercial and survey CAA and to the survey indices are also shown.

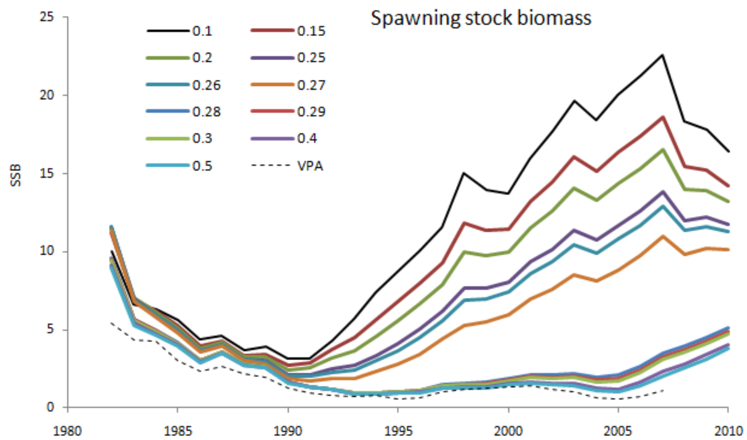

Fig. 11: Spawning stock biomass trajectories for Case 7 with different weightings (w^{CAA}) for the survey CAA data in the likelihood. The VPA results are also shown (Nitschke, 2008).

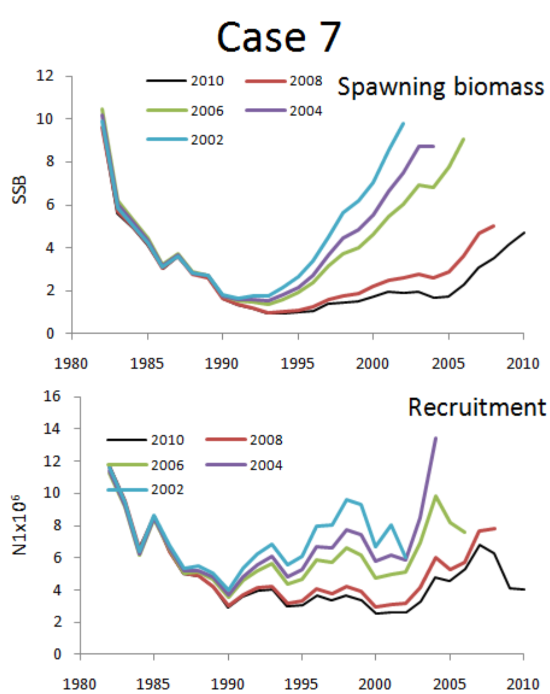

Fig. 12: Retrospective analysis of spawning biomass and recruitment for Case 7.

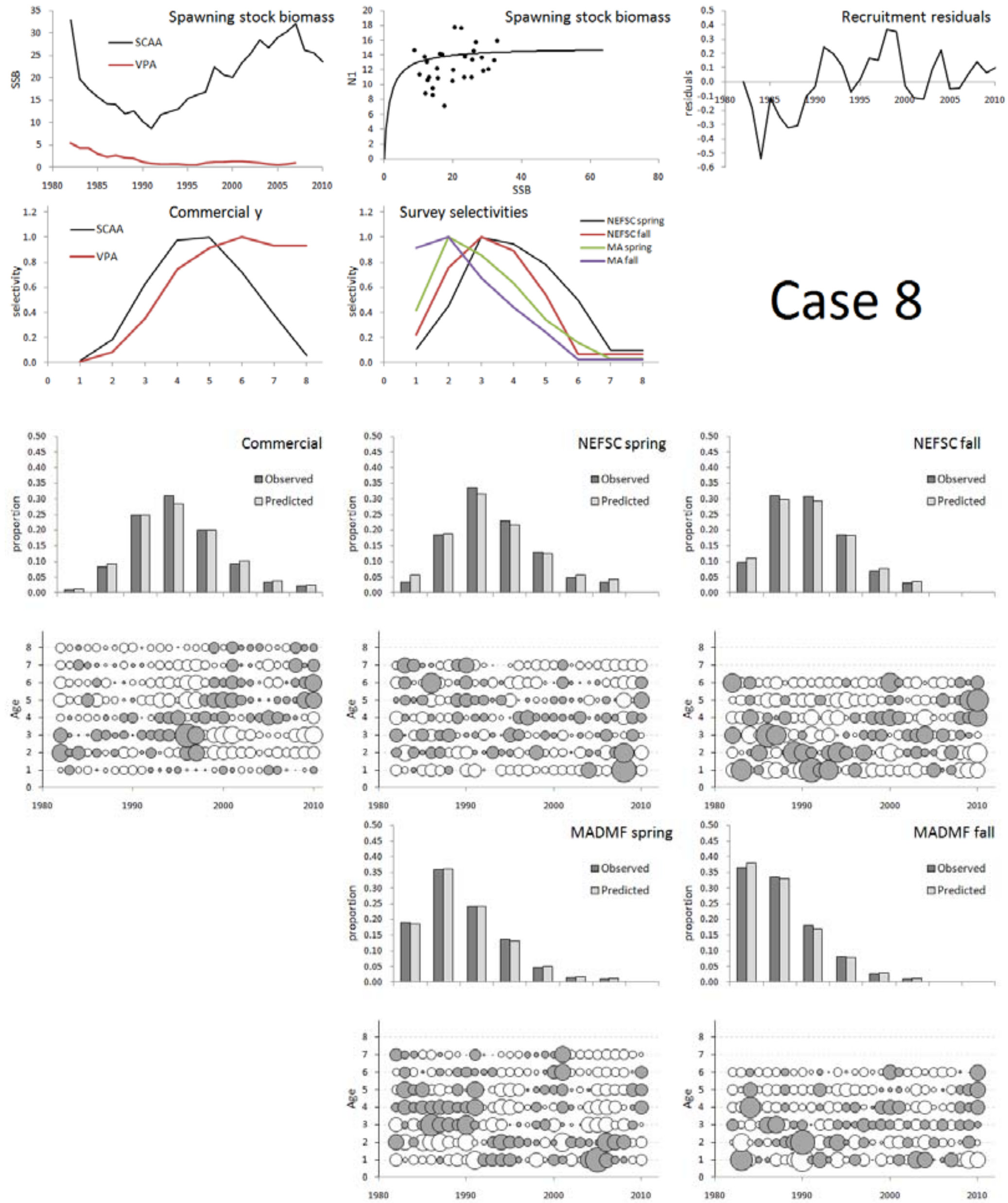

Fig. 13: Spawning stock biomass trajectories, stock-recruit relationship, recruitment residuals and selectivities for Case 8 (commercial selectivity domed). The fits to the commercial and survey CAA are also shown.

APPENDIX A – Data

Table A1: Total catch (metric tons) for Gulf of Maine winter flounder (Nitschke, 2011).

Year	Total catch (mt)	Year	Total catch (mt)
1982	6178	1997	660
1983	3035	1998	689
1984	2883	1999	399
1985	3327	2000	587
1986	1692	2001	756
1987	2713	2002	740
1988	1927	2003	801
1989	2315	2004	687
1990	1511	2005	387
1991	1136	2006	247
1992	947	2007	297
1993	778	2008	405
1994	640	2009	367
1995	776	2010	195
1996	674		

Table A2. Catch at age matrix (000s) for Gulf of Maine winter flounder (Nitschke, 2011).

	1	2	3	4	5	6	7	8+
1982	112	2883	5267	3487	1402	617	276	104
1983	135	915	1955	1838	857	362	158	133
1984	23	916	2077	1901	856	348	312	225
1985	31	288	1598	2122	1925	398	218	136
1986	49	505	928	851	373	353	102	62
1987	53	486	2004	1224	794	311	138	136
1988	23	471	1188	1177	361	248	123	89
1989	24	238	1353	1478	777	213	51	38
1990	9	263	836	1008	504	172	49	29
1991	18	304	864	610	234	119	57	41
1992	44	390	734	585	207	72	28	18
1993	28	197	758	669	149	69	9	3
1994	18	81	503	623	152	44	16	7
1995	27	70	335	765	392	122	18	18
1996	16	217	733	350	79	13	7	11
1997	19	286	592	449	117	22	8	12
1998	20	64	264	474	333	115	41	12
1999	7	13	79	240	227	103	29	28
2000	17	29	89	394	380	142	34	15
2001	13	21	84	384	432	242	101	56
2002	4	31	167	383	408	187	65	34
2003	9	41	168	390	419	247	78	46
2004	10	89	202	345	250	195	64	47
2005	15	54	165	259	139	55	17	16
2006	7	14	104	160	89	27	14	12
2007	5	23	93	193	135	57	16	9
2008	8	21	75	181	205	116	66	40
2009	6	22	54	146	219	144	41	26
2010	6	10	20	70	120	84	40	16

Table A3a. Total fishery mean weights-at-age (kg) for Gulf of Maine winter flounder (Nitschke, 2011).

	1	2	3	4	5	6	7	8+
1982	0.084	0.224	0.375	0.487	0.595	0.802	0.943	2.037
1983	0.123	0.257	0.358	0.502	0.644	0.795	0.946	1.164
1984	0.082	0.264	0.306	0.401	0.543	0.708	0.855	1.115
1985	0.043	0.174	0.312	0.447	0.584	0.809	0.927	1.122
1986	0.050	0.309	0.410	0.510	0.664	0.813	1.005	1.221
1987	0.035	0.259	0.392	0.527	0.690	0.858	1.070	1.284
1988	0.038	0.396	0.426	0.487	0.648	0.754	1.022	1.204
1989	0.040	0.229	0.427	0.582	0.629	1.004	1.175	1.397
1990	0.034	0.301	0.421	0.538	0.625	0.763	0.979	1.226
1991	0.038	0.277	0.451	0.583	0.599	0.695	0.744	0.929
1992	0.027	0.227	0.406	0.533	0.638	0.788	1.051	1.465
1993	0.028	0.238	0.367	0.439	0.645	0.667	1.115	1.453
1994	0.028	0.090	0.369	0.470	0.610	0.747	1.068	1.229
1995	0.038	0.105	0.341	0.421	0.535	0.635	0.833	1.563
1996	0.028	0.321	0.454	0.541	0.643	0.722	0.767	1.321
1997	0.038	0.240	0.421	0.512	0.628	0.889	0.784	0.921
1998	0.029	0.202	0.392	0.472	0.615	0.755	0.910	1.557
1999	0.039	0.114	0.377	0.487	0.542	0.665	0.838	1.219
2000	0.041	0.146	0.353	0.473	0.581	0.698	0.817	1.03
2001	0.034	0.115	0.319	0.448	0.538	0.693	0.852	1.194
2002	0.050	0.182	0.415	0.496	0.593	0.705	0.882	1.285
2003	0.035	0.156	0.366	0.482	0.560	0.704	0.889	1.436
2004	0.035	0.207	0.352	0.494	0.628	0.763	0.923	1.269
2005	0.042	0.172	0.380	0.505	0.669	0.895	1.038	1.346
2006	0.048	0.138	0.404	0.535	0.715	0.811	1.032	1.365
2007	0.043	0.200	0.386	0.487	0.639	0.815	0.964	1.476
2008	0.046	0.153	0.375	0.474	0.549	0.671	0.784	1.097
2009	0.043	0.155	0.329	0.449	0.565	0.678	0.692	1.115
2010	0.031	0.065	0.314	0.427	0.507	0.604	0.717	0.947

Table A3b. Spawning stock biomass mean weights-at-age (kg) for Gulf of Maine winter flounder (Nitschke, 2011).

	1	2	3	4	5	6	7	8+
1982	0.048	0.177	0.324	0.424	0.515	0.738	0.870	2.037
1983	0.084	0.147	0.283	0.434	0.560	0.688	0.871	1.164
1984	0.056	0.180	0.280	0.379	0.522	0.675	0.825	1.115
1985	0.016	0.119	0.287	0.370	0.484	0.663	0.810	1.122
1986	0.022	0.115	0.267	0.399	0.545	0.689	0.902	1.221
1987	0.010	0.114	0.348	0.465	0.593	0.755	0.933	1.284
1988	0.016	0.118	0.332	0.437	0.584	0.721	0.936	1.204
1989	0.015	0.093	0.411	0.498	0.554	0.807	0.941	1.397
1990	0.012	0.110	0.311	0.479	0.603	0.693	0.991	1.226
1991	0.016	0.097	0.368	0.495	0.568	0.659	0.753	0.929
1992	0.009	0.093	0.335	0.490	0.610	0.687	0.855	1.465
1993	0.016	0.080	0.289	0.422	0.586	0.652	0.937	1.453
1994	0.015	0.050	0.296	0.415	0.518	0.694	0.844	1.229
1995	0.013	0.054	0.175	0.394	0.501	0.622	0.789	1.563
1996	0.010	0.110	0.218	0.430	0.520	0.622	0.698	1.321
1997	0.017	0.082	0.368	0.482	0.583	0.756	0.752	0.921
1998	0.015	0.088	0.307	0.446	0.561	0.689	0.899	1.557
1999	0.020	0.058	0.276	0.437	0.506	0.640	0.795	1.219
2000	0.025	0.076	0.201	0.422	0.532	0.615	0.737	1.03
2001	0.015	0.069	0.216	0.398	0.505	0.635	0.771	1.194
2002	0.028	0.079	0.219	0.398	0.515	0.616	0.782	1.285
2003	0.014	0.088	0.258	0.447	0.527	0.646	0.792	1.436
2004	0.016	0.085	0.234	0.425	0.550	0.654	0.806	1.269
2005	0.023	0.078	0.281	0.422	0.575	0.750	0.890	1.346
2006	0.024	0.076	0.264	0.451	0.601	0.737	0.961	1.365
2007	0.023	0.098	0.231	0.444	0.585	0.763	0.884	1.476
2008	0.025	0.081	0.274	0.428	0.517	0.655	0.799	1.097
2009	0.035	0.084	0.224	0.410	0.518	0.610	0.681	1.115
2010	0.018	0.053	0.223	0.369	0.477	0.588	0.700	0.969

Table A3c. January-1 mean weights-at-age (kg) for Gulf of Maine winter flounder (Nitschke, 2011).

	1	2	3	4	5	6	7	8+
1982	0.048	0.177	0.324	0.424	0.515	0.738	0.870	2.037
1983	0.084	0.147	0.283	0.434	0.560	0.688	0.871	1.164
1984	0.056	0.180	0.280	0.379	0.522	0.675	0.825	1.115
1985	0.016	0.119	0.287	0.370	0.484	0.663	0.810	1.122
1986	0.022	0.115	0.267	0.399	0.545	0.689	0.902	1.221
1987	0.010	0.114	0.348	0.465	0.593	0.755	0.933	1.284
1988	0.016	0.118	0.332	0.437	0.584	0.721	0.936	1.204
1989	0.015	0.093	0.411	0.498	0.554	0.807	0.941	1.397
1990	0.012	0.110	0.311	0.479	0.603	0.693	0.991	1.226
1991	0.016	0.097	0.368	0.495	0.568	0.659	0.753	0.929
1992	0.009	0.093	0.335	0.490	0.610	0.687	0.855	1.465
1993	0.016	0.080	0.289	0.422	0.586	0.652	0.937	1.453
1994	0.015	0.050	0.296	0.415	0.518	0.694	0.844	1.229
1995	0.013	0.054	0.175	0.394	0.501	0.622	0.789	1.563
1996	0.010	0.110	0.218	0.430	0.520	0.622	0.698	1.321
1997	0.017	0.082	0.368	0.482	0.583	0.756	0.752	0.921
1998	0.015	0.088	0.307	0.446	0.561	0.689	0.899	1.557
1999	0.020	0.058	0.276	0.437	0.506	0.640	0.795	1.219
2000	0.025	0.076	0.201	0.422	0.532	0.615	0.737	1.03
2001	0.015	0.069	0.216	0.398	0.505	0.635	0.771	1.194
2002	0.028	0.079	0.219	0.398	0.515	0.616	0.782	1.285
2003	0.014	0.088	0.258	0.447	0.527	0.646	0.792	1.436
2004	0.016	0.085	0.234	0.425	0.550	0.654	0.806	1.269
2005	0.023	0.078	0.281	0.422	0.575	0.750	0.890	1.346
2006	0.024	0.076	0.264	0.451	0.601	0.737	0.961	1.365
2007	0.023	0.098	0.231	0.444	0.585	0.763	0.884	1.476
2008	0.025	0.081	0.274	0.428	0.517	0.655	0.799	1.097
2009	0.035	0.084	0.224	0.410	0.518	0.610	0.681	1.115
2010	0.018	0.053	0.223	0.369	0.477	0.588	0.700	0.969

Table A4: Proportion mature-at-age for Gulf of Maine winter flounder (Nitschke, 2011).

1	2	3	4	5	6	7	8+
0.00	0.04	0.35	0.88	0.99	1.00	1.00	1.00

Table A5: Survey data for Gulf of Maine winter flounder (Nitschke, 2011).

	NEFSC spring	NEFSC fall	MADMF spring	MADMF fall
Month	4	10	5	5
Ages	1-8+	1-8+	1-8+	1-8+
1982	7.67	4.201	61.61	108.20
1983	12.367	10.304	112.49	76.66
1984	5.155	7.732	68.95	39.54
1985	3.469	7.638	54.21	48.68
1986	2.342	2.502	68.98	44.65
1987	5.609	1.605	85.18	54.43
1988	6.897	3	54.04	38.42
1989	3.717	6.402	64.70	39.25
1990	5.415	3.527	82.13	67.66
1991	4.517	7.035	46.63	101.72
1992	3.932	10.447	79.00	87.58
1993	1.556	7.559	78.02	93.53
1994	3.481	4.87	72.58	67.79
1995	12.185	4.765	89.36	76.74
1996	2.736	10.099	70.49	77.01
1997	2.806	10.008	85.40	78.40
1998	2.001	3.218	77.77	98.45
1999	6.51	10.921	80.78	125.74
2000	10.383	12.705	162.19	99.95
2001	5.242	8.786	89.74	81.07
2002	12.066	10.691	91.08	65.81
2003	7.839	10.182	83.69	90.48
2004	3.879	2.763	79.12	107.59
2005	6.92	8.807	94.04	78.59
2006	4.173	7.117	85.55	86.99
2007	2.5	6.378	53.58	76.67
2008	11.543	13.319	46.86	90.92
2009	6.846	13.176	71.32	109.00
2010	5.023	12.046	68.24	104.67

Table A6a: NEFSC spring survey catch-at-age data for Gulf of Maine winter flounder (Nitschke, 2011).

	1	2	3	4	5	6	7	8+
1982	92.06	1075.75	1900.83	474.97	570.39	62.23	0.00	116.13
1983	229.12	401.15	2462.32	1546.13	918.71	560.03	654.61	149.20
1984	117.19	640.90	901.25	554.72	315.92	92.45	154.91	107.51
1985	3.36	289.22	823.35	330.86	329.13	49.86	86.58	28.77
1986	17.96	433.05	217.59	308.31	54.06	202.14	59.71	18.13
1987	81.71	891.46	1480.03	368.52	187.09	32.68	66.93	30.61
1988	332.32	610.85	1895.85	706.61	190.39	82.21	29.61	12.03
1989	0.00	260.85	636.15	586.17	366.68	64.58	96.26	69.40
1990	12.82	448.05	1042.22	522.76	487.56	235.44	4.20	277.58
1991	34.70	619.24	985.48	540.22	285.31	54.34	8.62	0.00
1992	153.40	577.22	533.12	529.81	270.53	96.15	34.81	5.71
1993	0.00	250.89	345.92	148.98	98.55	9.51	17.18	0.00
1994	13.49	403.22	645.77	470.88	310.94	103.70	0.00	0.00
1995	161.96	1226.23	3090.63	1658.95	493.72	49.30	138.51	0.00
1996	39.12	180.65	538.43	509.44	240.20	14.83	8.28	0.00
1997	28.93	284.63	413.07	499.20	249.38	59.71	18.08	17.18
1998	58.31	328.96	335.67	269.41	118.20	5.32	0.00	3.97
1999	172.59	654.05	1276.04	940.03	398.47	183.79	18.13	0.00
2000	85.68	859.33	2136.77	1399.95	900.91	330.30	65.87	32.12
2001	39.40	289.84	787.19	833.64	462.88	333.04	121.50	66.15
2002	89.04	914.29	1670.48	1999.27	1280.52	513.98	188.71	96.54
2003	65.42	356.38	1203.79	1294.40	895.20	430.20	77.06	64.47
2004	299.30	466.35	494.33	414.36	186.42	209.70	100.51	0.00
2005	64.08	866.55	1278.73	789.99	438.54	288.94	102.41	43.15
2006	35.37	126.48	1065.67	664.02	332.99	85.01	25.86	0.00
2007	70.18	287.04	349.44	418.44	217.81	38.73	17.52	0.00
2008	1524.69	2335.33	1503.76	654.45	358.68	73.93	9.29	0.00
2009	33.63	618.24	1489.88	1100.43	474.02	69.00	41.86	4.20
2010	20.32	158.60	819.32	752.16	685.34	316.42	39.51	19.59

Table A6b: NEFSC fall survey catch-at-age data for Gulf of Maine winter flounder (Nitschke, 2011).

	1	2	3	4	5	6	7	8+
1982	166.83	636.37	971.76	230.63	117.64	46.56	153.90	27.09
1983	1198.31	2012.87	1743.29	564.01	151.83	59.60	36.66	0.00
1984	250.50	1310.80	935.83	1216.16	332.60	124.30	61.90	95.31
1985	728.04	1533.42	1075.86	641.74	182.78	52.33	60.50	0.00
1986	16.85	403.67	645.88	272.60	30.61	11.42	0.00	18.92
1987	43.43	255.37	474.91	106.11	10.63	0.00	0.00	7.84
1988	237.79	572.96	338.53	394.66	85.91	30.89	18.13	0.00
1989	259.11	2015.33	792.01	419.62	52.66	37.72	0.00	6.27
1990	53.22	1039.03	610.79	221.90	30.61	12.03	6.04	0.00
1991	1452.33	1585.02	607.55	215.52	17.01	26.19	16.68	0.00
1992	1073.90	2072.97	1341.52	913.06	424.66	8.28	12.09	0.00
1993	927.61	1765.90	1015.75	385.09	130.45	5.65	0.00	0.00
1994	208.97	1288.30	846.18	354.03	22.05	5.65	0.00	0.00
1995	200.97	865.54	869.63	563.11	81.60	86.02	0.00	0.00
1996	987.88	1328.70	1440.52	1472.48	334.78	80.81	0.00	0.00
1997	231.19	2418.72	1787.72	823.63	320.68	18.80	0.00	0.00
1998	124.41	498.25	630.83	436.13	77.96	33.24	0.00	0.00
1999	453.37	1552.06	2040.57	1595.32	381.06	81.32	8.00	0.00
2000	349.16	1134.00	2238.63	1980.58	780.70	535.30	91.73	0.00
2001	200.58	927.38	1451.49	1564.59	539.55	203.93	23.73	5.93
2002	374.90	1535.49	1921.20	1317.96	698.88	109.52	11.70	13.32
2003	310.55	1779.16	1912.69	1004.00	562.33	111.15	18.24	0.00
2004	162.91	510.73	596.58	107.28	93.68	16.68	36.82	21.71
2005	699.89	1714.19	1313.43	751.88	327.61	54.51	30.67	36.49
2006	361.92	589.64	1718.72	758.82	490.53	22.22	41.25	0.00
2007	434.28	1174.69	760.78	774.43	315.69	109.30	0.00	0.00
2008	257.83	1391.66	2267.90	1873.80	1145.37	485.99	0.00	31.56
2009	80.31	1558.66	2246.74	1757.39	1320.20	382.96	20.99	6.16
2010	21.77	576.66	1908.49	2241.48	1448.19	307.47	190.11	46.84

Table A6c: Massachusetts spring survey catch-at-age data for Gulf of Maine winter flounder (Nitschke, 2011).

	1	2	3	4	5	6	7	8+
1982	1658.16	6361.20	1836.79	1947.30	419.94	111.03	354.05	14.45
1983	3175.87	6278.94	6590.91	4132.55	1984.33	537.40	211.29	270.09
1984	1309.41	5596.43	3427.98	2620.57	907.69	55.09	216.20	82.31
1985	2136.45	1672.36	3405.67	2706.69	1008.58	146.04	49.75	23.13
1986	2295.95	3780.69	5293.35	2403.82	349.06	43.77	16.58	39.63
1987	3593.98	3635.32	7003.94	2556.53	169.83	334.75	85.54	182.30
1988	1650.94	3169.97	3910.95	2118.61	170.88	56.20	13.38	45.67
1989	2065.50	4331.80	3825.33	2021.71	823.53	166.82	28.18	75.85
1990	3265.41	4208.90	6244.24	2282.77	471.16	312.09	108.94	38.78
1991	984.48	3502.56	2550.99	1649.27	683.00	110.68	53.05	103.32
1992	4447.96	6709.79	2828.85	1562.76	476.95	173.95	39.07	48.72
1993	4039.88	7104.62	2796.09	1358.03	435.10	264.34	49.42	38.14
1994	3310.73	7781.04	3075.77	1000.02	169.00	26.08	36.60	21.32
1995	4474.23	7433.04	4751.29	1288.26	294.75	117.69	32.78	32.10
1996	3212.26	5900.09	3246.03	1531.28	419.30	165.27	42.62	17.48
1997	3199.00	7320.28	3758.75	1838.01	1030.33	220.03	134.86	105.44
1998	2106.16	5871.00	4368.13	2399.67	833.70	248.73	169.48	37.69
1999	3181.83	5455.98	4427.92	2024.19	1045.28	268.24	134.22	116.41
2000	5997.82	13694.80	6182.92	3527.20	2279.87	1248.05	381.06	128.22
2001	3038.06	2156.92	5664.30	4172.67	1605.77	1067.98	528.95	268.38
2002	1891.06	6962.83	4197.19	3884.95	1482.33	263.39	94.94	2.54
2003	3172.08	6338.79	3738.01	2264.07	1262.44	353.59	108.26	18.25
2004	5569.03	6461.18	1671.73	1208.82	911.14	381.53	70.33	37.83
2005	7223.85	8227.77	2691.42	870.50	305.58	57.54	7.07	5.98
2006	4302.98	8758.47	2948.09	1189.54	331.10	70.95	26.99	10.00
2007	2302.69	4893.18	2081.50	1254.46	398.77	94.72	13.44	8.78
2008	2072.08	4453.26	1452.02	1133.50	417.03	93.32	27.65	13.15
2009	2115.48	4797.99	3989.67	1995.28	1290.75	364.95	103.95	45.75
2010	1832.75	3890.83	3509.46	2881.02	1191.91	539.98	194.14	28.37

Table A6d: Massachusetts fall survey catch-at-age data for Gulf of Maine winter flounder (Nitschke, 2011).

	1	2	3	4	5	6	7	8+
1982	9419.66	7334.77	4407.41	810.44	147.11	46.47	20.97	20.49
1983	8909.33	3589.56	2474.79	572.97	229.08	14.04	1.57	13.73
1984	1715.39	2715.77	1434.21	1640.61	449.45	121.07	53.19	8.84
1985	4897.43	2810.59	1411.26	638.41	160.34	38.18	18.47	8.58
1986	3738.84	3230.42	1830.09	319.49	43.50	0.00	0.00	21.28
1987	3325.39	4315.82	3177.09	249.97	9.26	15.26	23.15	24.37
1988	2789.74	3194.71	935.84	672.78	185.46	99.42	34.14	0.00
1989	2794.61	3609.79	1286.50	292.09	65.44	22.56	10.62	10.62
1990	1801.47	9234.03	2325.97	532.45	48.99	0.00	0.00	7.15
1991	10419.18	6327.18	2900.09	604.12	8.99	70.76	26.93	0.00
1992	9367.51	4532.62	1891.98	1295.20	675.75	67.61	21.44	57.21
1993	7523.20	7769.60	2747.19	747.78	331.78	65.28	21.44	21.46
1994	2918.62	6752.77	3179.56	1042.23	47.30	0.00	5.38	5.46
1995	5419.59	4880.19	3341.76	1844.44	133.38	76.55	10.93	34.33
1996	7524.31	3352.89	2575.63	1884.97	265.84	92.20	4.78	4.78
1997	4814.83	6418.38	3467.90	1051.98	317.18	14.93	0.00	0.00
1998	8603.17	5826.52	3839.39	1490.50	272.57	155.48	15.22	20.72
1999	7886.42	8744.32	4914.05	3132.82	783.29	126.35	15.71	26.70
2000	5374.73	5949.39	4929.16	2799.49	787.06	559.15	132.26	0.00
2001	6126.97	3548.97	2918.46	2868.44	787.16	327.31	37.26	22.14
2002	3776.65	4675.99	2613.62	1531.07	686.63	93.81	16.02	15.98
2003	10176.70	4439.24	2015.05	979.79	458.87	61.36	25.65	0.00
2004	11968.46	4887.41	3668.01	544.31	411.16	145.38	127.40	16.35
2005	5186.41	7090.88	2258.30	1090.90	435.57	40.02	31.92	38.62
2006	6248.84	4626.76	4821.72	1472.35	616.90	11.46	39.26	9.48
2007	7590.02	4281.27	1958.21	1358.60	422.81	107.75	14.14	2.76
2008	5706.92	5761.15	3592.51	2148.16	1096.47	307.90	0.00	35.38
2009	4210.96	9523.65	4708.05	2278.75	1288.61	365.94	16.37	34.91
2010	4923.51	6220.98	4294.42	3028.39	1596.86	618.12	341.24	66.76

Appendix B - The Age-Structured Production Model

The model used for these assessments is an Age-Structured Production Model (ASPM) (e.g. Hilborn, 1990). Models of this type fall within the more general class of Statistical Catch-at-Age Analyses. The approach used in an ASPM assessment involves constructing an age-structured model of the population dynamics and fitting it to the available abundance indices by maximising the likelihood function. The model equations and the general specifications of the model are described below, followed by details of the contributions to the (penalised) log-likelihood function from the different sources of data available and assumptions concerning the stock-recruitment relationship. Quasi-Newton minimization is used to minimize the total negative log-likelihood function (the package AD Model Builder™, Otter Research, Ltd is used for this purpose).

B.1. Population dynamics

B.1.1 Numbers-at-age

The resource dynamics are modelled by the following set of population dynamics equations:

$$N_{y+1,1} = R_{y+1} \tag{B1}$$

$$N_{y+1,a+1} = \left(N_{y,a}\, e^{-M_{y,a}/2} - C_{y,a}\right) e^{-M_{y,a}/2} \qquad \text{for } 1 \le a \le m-2 \tag{B2}$$

$$N_{y+1,m} = \left(N_{y,m-1}\, e^{-M_{y,m-1}/2} - C_{y,m-1}\right) e^{-M_{y,m-1}/2} + \left(N_{y,m}\, e^{-M_{y,m}/2} - C_{y,m}\right) e^{-M_{y,m}/2} \tag{B3}$$

where

$N_{y,a}$ is the number of fish of age *a* at the start of year *y* (which refers to a calendar year),

R_y is the recruitment (number of 1-year-old fish) at the start of year *y*,

$M_{y,a}$ denotes the natural mortality rate for fish of age *a* in year *y*,

$C_{y,a}$ is the predicted number of fish of age *a* caught in year *y*, and

m is the maximum age considered (age 8 here) (taken to be a plus-group).

B.1.2. Recruitment

The number of recruits at the start of year *y* is assumed to follow a Beverton-Holt stock-recruit curve, and allowing for annual fluctuation about the deterministic relationship:

$$R_y = \frac{\alpha B_y^{sp}}{\beta + B_y^{sp}} e^{\left(\varsigma_y - \left(\sigma_R^1\right)^2/2\right)} \tag{B4}$$

where

α and β are spawning biomass-recruitment relationship parameters,

ς_y reflects fluctuation about the expected recruitment for year *y*, which is assumed to be normally distributed with standard deviation $\sigma_R = 0.5$

B_y^{sp} is the spawning biomass, computed as:

$$B_y^{sp} = \sum_{a=1}^{m} f_{y,a} w_{y,a}^{strt} N_{y,a} e^{-M_{y,a}\delta} \qquad \text{(B5)}$$

where

$w_{y,a}^{sp}$ is the mass of fish of age *a* during spawning, and

$f_{y,a}$ is the proportion of fish of age *a* that are mature,

δ is the proportion of the natural mortality that occurs before spawning (0.25 here).

B.1.3. Total catch and catches-at-age

The catch by mass in year *y* is given by:

$$C_y = \sum_{a=1}^{m} w_{y,a}^{mid}\ C_{y,a} = \sum_{a=1}^{m} w_{y,a}^{mid}\ N_{y,a}\ e^{-M_{y,a}/2}\ S_{y,a}\ F_y \qquad \text{(B6)}$$

where

$w_{y,a}^{mid}$ denotes the mass of fish of age *a* landed in year *y*,

$C_{y,a}$ is the catch-at-age, i.e. the number of fish of age *a*, caught in year *y*,

$S_{y,a}$ is the commercial selectivity (i.e. combination of availability and vulnerability to fishing gear) at age *a* for year *y*; when $S_{y,a}$ = 1, the age-class *a* is said to be fully selected, and

F_y is the proportion of a fully selected age class that is fished.

The model estimate of the mid-year exploitable ("available") component of biomass is calculated by converting the numbers-at-age into mid-year mass-at-age (using the individual weights of the landed fish) and applying natural and fishing mortality for half the year:

$$B_y^{ex} = \sum_{a=1}^{m} w_{y,a}^{mid} S_{y,a} N_{y,a} e^{-M_{y,a}/2} (1 - S_{y,a} F_y\ /2) \qquad \text{(B7)}$$

For survey estimates (in numbers):

$$N_y^{surv,i} = \sum_{a=1}^{m} S_a^i N_{y,a} e^{-M_{y,a}\frac{\varpi^1}{12}} \left(1 - S_{y,a} F_y\ \frac{\varpi^1}{12}\right) \qquad \text{(B8)}$$

where

S_a^i is the survey selectivity for age *a* and survey *i*,

ϖ^i is the month in which survey *i* has taken place.

B.1.4. Initial conditions

For the first year (y_0) considered in the model therefore, the stock is assumed to be at a level $B_{y_0}^{sp}$ (estimated in the model fitting procedure), with the starting age structure:

$$N_{y_0,a} = R_{start} N_{start,a} \qquad \text{for } 1 \le a \le m \tag{B9}$$

where

$$N_{start,1} = 1 \tag{B10}$$

$$N_{start,a} = N_{start,a-1} e^{-M_{y_0,a-1}} (1 - \phi S_{y_0,a-1}) \qquad \text{for } 2 \le a \le m-1 \tag{B11}$$

$$N_{start,m} = N_{start,m-1} e^{-M_{y_0,m-1}} (1 - \phi S_{y_0,m-1}) \big/ (1 - e^{-M_{y_0,m}} (1 - \phi S_{y_0,m})) \tag{B12}$$

where ϕ characterises the average fishing proportion over the years immediately preceding y_0.

B.2. The (penalised) likelihood function

The model is fit to survey abundance indices, and commercial and survey catch-at-age data to estimate model parameters (which may include residuals about the stock-recruitment function, the fishing selectivities, the annual catches or natural mortality, facilitated through the incorporation of the penalty functions described below). Contributions by each of these to the negative of the (penalised) log-likelihood (- $\ell\text{n}L$) are as follows.

B.2.1. Survey abundance data

The likelihood is calculated assuming that an observed survey index is log-normally distributed about its expected value:

$$I_y^i = \hat{I}_y^i \exp\left(\varepsilon_y^i\right) \quad \text{or} \quad \varepsilon_y^i = \ell\text{n}\left(I_y^i\right) - \ell\text{n}\left(\hat{I}_y^i\right) \tag{B13}$$

where

I_y^i is the survey index for year *y* and series *i*,

$\hat{I}_y^i = \hat{q}^i N_y^{surv,i}$ is the corresponding model estimate, where $N_y^{surv,i}$ is the model estimate, given by equation (B8),

$\hat{q}^i$ is the constant of proportionality (catchability) for index *i*, and

ε_y^i from $N\left(0, \left(\sigma_y^i\right)^2\right)$.

For these analyses, selectivities are estimated as detailed in section B.3.1 below.

The contribution of the survey abundance data to the negative of the log-likelihood function (after removal of constants) is then given by:

$$-\ell\mathrm{n}\, L^{survey} = \sum_i \sum_y \left[\ell\mathrm{n}\left(\sigma_y^i\right) + \left(\varepsilon_y^i\right)^2 / 2\left(\sigma_y^i\right)^2\right] \quad \text{(B14)}$$

where

σ_y^i is the standard deviation of the residuals for the logarithm of index *i* in year *y*.

Homoscedasticity of residuals is assumed, so that $\sigma_y^i = \sigma^i$ is estimated in the fitting procedure by its maximum likelihood value:

$$\hat{\sigma}^i = \sqrt{1/n_i \sum_y \left(\ell\mathrm{n}(I_y^i) - \ell\mathrm{n}(q^i N_y^{surv,i})\right)^2} \quad \text{(B15)}$$

where

n_i is the number of data points for survey index *i*.

The catchability coefficient q^i for survey index *i* is estimated by its maximum likelihood value:

$$\ell n\, \hat{q}^i = 1/n_i \sum_y \left(\ln I_y^i - \ln N_y^{surv,i}\right) \quad \text{(B16)}$$

To allow for first order serial correlation between the survey residuals, a serial correlation coefficient ρ^i would be estimated for each survey index:

$$\varepsilon_y^i = \lambda_y^i - \rho\lambda_{y-1}^i \quad \text{(B17)}$$

where

$$\lambda_y^i = \ell\mathrm{n}\left(I_y^i\right) - \ell\mathrm{n}\left(\hat{I}_y^i\right)$$

and the summation in equation (B.16) extends over one less year.

B.2.2. Commercial catches-at-age

The contribution of the catch-at-age data to the negative of the log-likelihood function under the assumption of an "adjusted" lognormal error distribution is given by:

$$-\ell\mathrm{n}\, L^{CAA} = w^{CAA} \sum_y \sum_a \left[\ell n\left(\sigma_{com} / \sqrt{p_{y,a}}\right) + p_{y,a}\left(\ell n\, p_{y,a} - \ell n\, \hat{p}_{y,a}\right)^2 / 2\left(\sigma_{com}\right)^2\right]$$

(B18)

where

w^{comCAA} is a multiplicative factor to downweight the commercial CAA likelihood,

$p_{y,a} = C_{y,a} / \sum_{a'} C_{y,a'}$ is the observed proportion of fish caught in year *y* that are of age *a*,

$\hat{p}_{y,a} = \hat{C}_{y,a} / \sum_{a'} \hat{C}_{y,a'}$ is the model-predicted proportion of fish caught in year *y* that are of age *a*, where

$$\hat{C}_{y,a} = N_{y,a}\, e^{-M_{y,a}/2}\, S_{y,a}\, F_y \qquad \text{(B19)}$$

and

σ_{com} is the standard deviation associated with the catch-at-age data, which is estimated in the fitting procedure by:

$$\hat{\sigma}_{com} = \sqrt{\sum_y \sum_a p_{y,a} \left(\ell n\, p_{y,a} - \ell n\, \hat{p}_{y,a}\right)^2 / \sum_y \sum_a 1} \qquad \text{(B20)}$$

B.2.3. Survey catches-at-age

The survey catches-at-age are incorporated into the negative of the log-likelihood in an analogous manner to the commercial catches-at-age (thus they are also weighted by a factor $w^{survCAA}$), assuming an adjusted log-normal error distribution (equation (B18)) where:

$p_{y,a} = C^{surv}_{y,a} / \sum_{a'} C^{surv}_{y,a'}$ is the observed proportion of fish of age *a* in year *y*, with

$$C^{surv,i}_{y,a} = S^i_a N_{y,a} e^{-M_{y,a}\frac{\varpi^1}{12}} \left(1 - S_{y,a} F_y \frac{\varpi^1}{12}\right) \qquad \text{(B21)}$$

$\hat{p}_{y,a}$ is the expected proportion of fish of age *a* in year *y* in the survey.

B.2.4. Stock-recruitment function residuals

The stock-recruitment residuals are assumed to be log-normally distributed. Thus, the contribution of the recruitment residuals to the negative of the (now penalised) log-likelihood function is given by:

$$-\ell n L^{SRpen} = \sum_{y=y1}^{1988} \left[\varepsilon_y^2 / 2\left(\sigma_R^1\right)^2\right] + \sum_{1989}^{y2} \left[\varepsilon_y^2 / 2\left(\sigma_R^2\right)^2\right] \qquad \text{(B22)}$$

where

ε_y from $N\left(0, (\sigma_R)^2\right)$

B.3. Model parameters

B.3.1. Fishing selectivity-at-age:

The commercial selectivity is estimated separately for ages 1 to 4 and is assumed to be flat for ages 5 and above (except for case 8) for which selectivity is also estimated separately for ages 5 and above. The survey fishing selectivities are estimated separately for ages 1 to a_{plus} (the plus group age) and flat thereafter. a_{plus}=7 for the spring surveys and 6 for the fall surveys.

B.3.2.: Other parameters reported in Table 1 and elsewhere

σ_R_out

$$\sigma_R\_\text{out} = \sum_{y=y1}^{y2} (\varsigma_y)^2 \Big/ \sum_{y=y1}^{y2} 1 \tag{B23}$$

where *y*1=1982 and *y*2=2010.

Calculation of MSY

The equilibrium catch for a fully selected fishing proportion *F* is calculated as:

$$C(F) = \sum_a w_a^{mid} S_a F N_a(F) e^{-(M_a/2)} \tag{B24}$$

where $w_a^{mid} = \sum_{y1=2006}^{2010} w_{y,a}^{mid} \Big/ 5$, $S_a = S_{2010,a}$ and $M_a = M_{2010,a}$

and where numbers-at-age *a* are given by:

$$N_a(F) = \begin{cases} R_1(F) & \text{for } a = 1 \\ N_{a-1}(F) e^{-M_{a-1}} (1 - S_{a-1}F) & \text{for } 1 < a < m \\ \dfrac{N_{m-1}(F) e^{-M_{m-1}} (1 - S_{m-1}F)}{\left(1 - e^{-M_m}(1 - S_m F)\right)} & \text{for } a = m \end{cases} \tag{B25}$$

where

$$R_1(F) = \frac{\alpha B^{sp}(F)}{\beta + B^{sp}(F)} \tag{B26}$$

The maximum of $C(F)$ is then found by searching over *F* to give F_{MSY}, with the associated spawning biomass and yield given by

$$B_{\text{MSY}}^{sp} = \sum_a f_a w_a^{strt} N_a(F_{\text{MSY}}) e^{-M_a \delta} \tag{B27}$$

$$MSY = \sum_a w_a^{mid} S_a F_{\text{MSY}} N_a(F_{\text{MSY}}) e^{-(M_a/2)} \tag{B28}$$

where $w_a^{strt} = \sum_{y1=2006}^{2010} w_{y,a}^{strt} \Big/ 5$ and $f_a = \sum_{y1=2006}^{2010} f_{y,a} \Big/ 5$

ADDITIONAL REFERENCE

Hilborn, R. 1990. Estimating the parameters of full age-structured models from catch and abundance data. International North Pacific Fisheries Commission Bulletin, 50: 207-213.

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